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INSTITUTE OF THE AERONAUTICAL SCIENCES

JANUARY-Dec 1951

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ALL new Cessna Models of the 190 Series are now equipped with Goodyear Cross-Wind Landing Wheels for greater serviceability and safety. For with these castered wheels aircraft can both take off and land regardless of wind direction. This makes it possible to operate these new Cessnas even from single strip airports when the wind is at right angles to the runway. Already in use on some commercial and military aircraft, the Goodyear Cross-Wind Landing Wheel opens a new era in flying. For full information about Goodyear Aviation Products, write:

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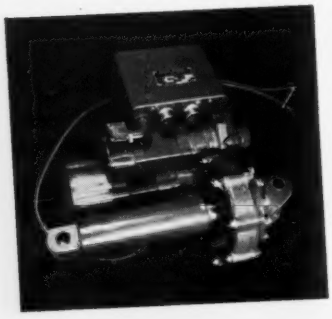
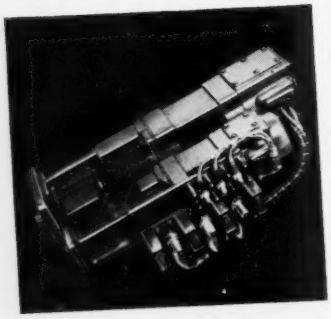
EEMCO technical bulletin

New Electric Power Units Foretell Era of Pushbutton Flight ... Faster aircraft and busier pilots are pushing automatic flight devices into the forefront. The development of versatile fool-proof power units to actuate control surfaces in conjunction with automatic pilots is a primary factor in achieving pushbutton flight. Such units are being produced by EEMCO in close cooperation with the designers and builders of tomorrow's aircraft.



Stabilizer Actuator for Large Jet Fighters ... One such "radical" advance is the motor actuator used on a new jet fighter. This unit incorporates two motors of different size, driving into individual gear reductions to operate the screw jack. Each fulfills a particular need and is not to be considered a standby. The small motor of 1/10 h.p. output operates practically continuously under control of the automatic pilot and provides a rate of travel to jack of 6/100" per sec. The large intermittent duty 3.3 h.p. motor provides manual operation of screw jack by pilot for maneuvering and extreme situations with a rate of travel of 7/10" per sec. Normal operating load of unit 11,000 lbs....28 volt operation. Equipment includes overload and travel limit switches, radio noise filters, position indicator and non-jamming stops.



Double Motor Power Unit for Horizontal Stabilizer ... A similarly unconventional motor arrangement operates the horizontal stabilizer actuator on a turbo-prop aircraft of recent design. A small continuous duty motor of 1/15th h.p. operating through a gear reduction is used for automatic flight and a large intermittent duty 3-1/2 h.p. with direct drive of 12,000 rpm is used for manual operation. The unique feature again is that it provides a large power source for maneuvering and a smaller unit for trimming in flight in small increments through the automatic pilot.

EEMCO Design and Testing Service Solves Difficult Actuator and Motor Design Problems...Tell us your requirements on current motor or actuator design problems. Include preliminary data on type of unit, specific function, special requirements, operating conditions, motor and actuator specifications and any available drawings, diagrams and tables.

SEND FOR FREE PERFORMANCE CHARTS AND DESIGN DRAWINGS...*Executives and engineering and design personnel making request on Company letterhead will be placed on mailing list for performance and design drawings of EEMCO designs for file and reference.*

EEMCO

ELECTRICAL ENGINEERING and MFG. Corp.

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AERONAUTICAL ENGINEERING REVIEW

Cover—Bell Aircraft Corporation's H-12 is the largest helicopter in the Bell series, marked by a single-rotor system and the Bell-patented stabilizer bar. The H-12 has a cruising speed of 85 m.p.h. and a top speed in excess of 120 m.p.h. It can carry ten persons and a pilot and has a useful load of over a ton. It is powered by a Pratt and Whitney R-1340 600-hp. engine.

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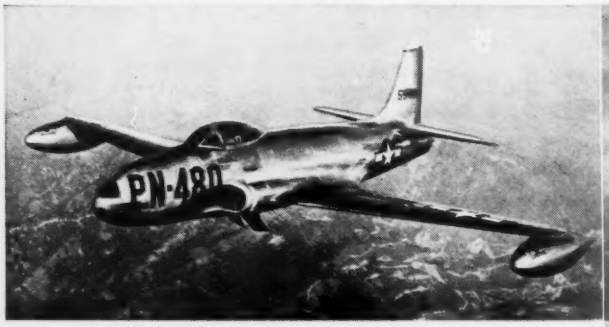
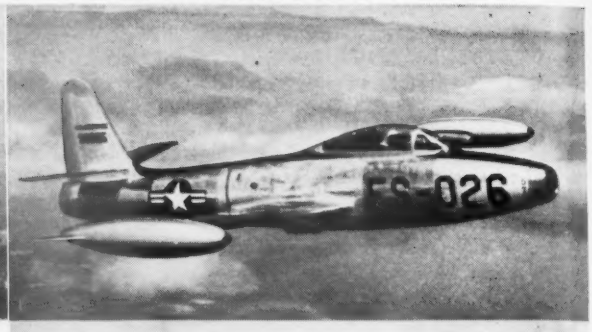
LOCKHEED F-80 SHOOTING STAR POWERED BY ALLISON J33 TURBO-JET



REPUBLIC F-84 THUNDERJET POWERED BY ALLISON J35 TURBO-JET



Experience where it counts most --*in the air*

The U. S. Air Force and U. S. Navy have accumulated more than 500,000 hours of actual flight operation with Allison Turbo-Jet engines in the aeroplanes shown on this page. This is more time *in the air* than the jet engines of any other manufacturer in the world.

Represented in this broad background of experience are thousands of hours of flight time on both J35 axial and J33 centrifugal flow engines — with and without afterburners — on the two models.

Now two new Navy planes are flying with Allison Turbo-Prop power. Here, too, Allison is the leader with its Navy-sponsored T40 twin Turbo-Prop engines out in front gaining in-the-air experience.

It's experience that counts — and these turbine engines have it where it counts most — in the air — in these airplanes.

Allison J33 engines also lend assistance to reciprocating engines in the Martin P4M and North American AJ-1.

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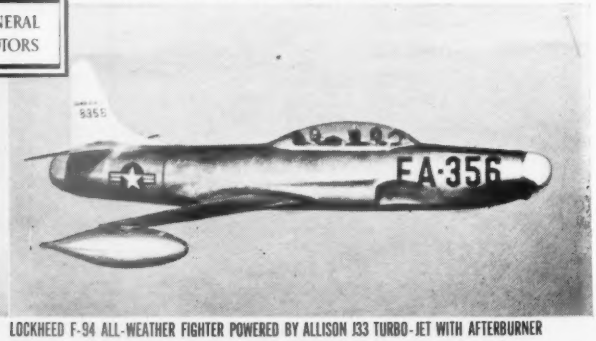
GRUMMAN F9F-3 PANTHER POWERED BY ALLISON J33 TURBO-JET

NORTHROP F-89 SCORPION POWERED BY TWO ALLISON J35 TURBO-JETS WITH AFTERBURNERS

DOUGLAS A2D SKYSHARK POWERED BY ALLISON T40 TURBO-PROP

CONSOLIDATED P5Y FLYING BOAT POWERED BY FOUR ALLISON T40 TWIN TURBO-PROPS



LOCKHEED F-94 ALL-WEATHER FIGHTER POWERED BY ALLISON J33 TURBO-JET WITH AFTERBURNER

I. A. S. News

A Record of People and Events of Interest to Institute Members

James E. Webb To Be Speaker at Honors Night Dinner

Speaker Is U.S. Under Secretary of State; Awards and Honors To Be Presented; Technical Sessions Tentatively Set.

GUEST OF HONOR AND PRINCIPAL SPEAKER at the Honors Night Dinner of the Institute of the Aeronautical Sciences will be James Edwin Webb, Under Secretary of State, Department of State, U.S. Government. The dinner will be held on Monday, January 29, the first day of the Nineteenth Annual Meeting, at the Hotel Astor in New York City.

James H. "Dutch" Kindelberger, as one of his last official acts in the capacity of 1950 I.A.S. President, will introduce the speaker. At the dinner, Honorary Fellowships and Fellowships for 1950 will be conferred, and the following awards will be presented: The John Jeffries Award, The Robert M. Losey Award, The Sylvanus Albert Reed Award, and The Lawrence Sperry Award.

▸ **The Speaker**—Mr. Webb was nominated to his present position by President Truman in January, 1949, and shortly thereafter was appointed as State Department member to the Air Coordinating Committee. Prior to his becoming Under Secretary of State, he had been Director of the Bureau of the Budget since July, 1946, and had directed the preparation and presentation of three of the four postwar Budgets of the U.S. Government.

A native of North Carolina, Mr. Webb attended the Oxford (N.C.) High School and the University of North Carolina. He was graduated from the latter in 1928 with an A.B. degree. He remained at the University for another year as Secretary of the Bureau of Educational Research. He later studied law and was a law clerk and stenographer in the Oxford law firm of Parham and Lassiter.

In 1930, Mr. Webb enlisted in the Marine Corps Reserve as a student aviator and received his flight training at the Pensacola Naval Air Station, Fla. Commissioned in 1931 as a Second Lieutenant, Fleet Marine Corps Reserve, he was on active flying duty for a year at Quantico, Va. Subsequently, he served as Commanding Officer of the Marine Reserve Aviation Squadron at Anacostia, Washington, D.C.

Mr. Webb first came to Washington in 1932 as Secretary to Representative Edward W. Pou, of the Fourth North Carolina District. Two years later, he entered the Washington law office of O. Max Gardner, a former Governor of North Carolina. At about this same time, Mr. Webb attended night classes of the George Washington University Law School and in 1936 was admitted to the District of Columbia Bar.

Mr. Webb went to New York in 1936 as Personnel Director and Assistant to the President of Sperry Gyroscope Company. In 1941, he was named Secretary and Treasurer of the company and 2 years later became a Vice-President of Sperry Gyroscope.

Returning to active duty in 1944 with the rank of Major in the Marine Corps, Mr. Webb was attached to the Ninth Marine Aircraft Wing and served as Commanding Officer of the First Marine Air Warning Group.

Speaker: *James E. Webb, Under Secretary of State, will deliver the lecture on the occasion of the Honors Night Dinner.*

Mr. Webb has been a member of the Board of Directors and of the Executive Committee of the National Aeronautic Association, a member of the Board of Directors of the Private Flyers Association, and a member of the Aviation Committee of the New York World's Fair.

▸ **Technical Sessions**—The schedule for the Technical Sessions, as tentatively set up at the time this issue went to press, will be found on page 7.

National Meetings Calendar

Jan. 29–31, Feb. 1, 1951 Nineteenth Annual Meeting, New York

March 16, 1951 Flight Propulsion Meeting, Cleveland

(For details see page 97)

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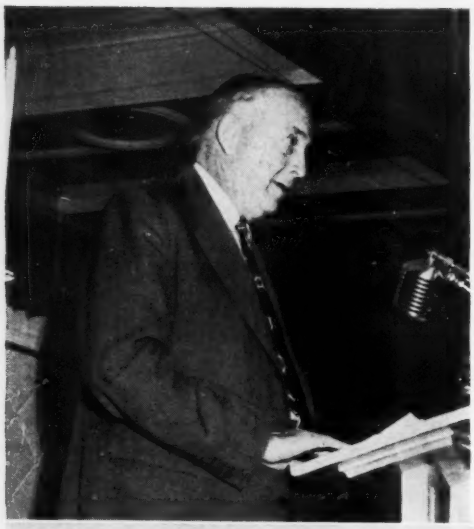

I.A.S. NAVY INSPECTION TOUR

October 26–27, 1950

At the invitation of Rear Adm. A. M. Pride, Chief of the Bureau of Aeronautics, approximately 110 security-cleared representatives of I.A.S. Corporate Member companies visited the Naval Air Material Center, Philadelphia, and the Naval Air Development Center, Johnsville, Pa. An impressive full-day program at each facility was arranged and directed by Rear Adm. Rico Botta and Capt. S. B. Spangler, commanding officers, respectively, of the two Centers.

(Left) **Honorable D. A. Kimball, Under Secretary of the Navy.**

(Above) **I.A.S. visitors at U.S. Naval Air Material Center.**

An informal reception and dinner, attended by the tour-group, Naval and Air Force officers, and members of the I.A.S. Philadelphia Section, was held at the Hotel Warwick on the evening of the 26th. Here, the Under Secretary of the Navy, the Honorable Dan A. Kimball, was guest of honor and principal speaker. While Mr. Kimball's interesting talk was "off the record," some of the remarks from Admiral Pride's introductory address may be found on pp. 16–17 of this

(Right) **Rear Adm. C. M. Bolster and Capt. S. B. Spangler.**

Highlights of the Technical Sessions of the Nineteenth Annual Meeting

Two New Sessions Added This Year

Electronics and Hypersonics will be included in this year's calendar at the Nineteenth Annual Meeting of the Institute of the Aeronautical Sciences, which will be held at the Hotel Astor, New York City, from January 29 to February 1, 1951, inclusive.

Recognizing that Electronics can no longer be considered a subordinate field of communications, 1 day of the 4-day Annual Meeting will be devoted entirely to this subject. In cooperation with the Institute of Radio Engineers and the Institute of Navigation, both a morning and an afternoon session have been planned. Generally speaking, the trend of these sessions will be away from research problems and toward subject matter that presents operational problems. Accordingly, the two Electronic sessions are to be devoted essentially to the requirements of aviation and electronic personnel.

The morning session will be devoted to problems of air-borne electronic equipment; the afternoon session will concern itself mainly with problems of all-weather flying. Among the topics to be covered are air-borne power supply for electronic and servo equipment, problems of packaging air-borne electronic equipment (e.g., weight, pressurization, maintenance, tropicalization, temperature range, and mounting), and problems of air-borne antenna and of frequency allocations for air-borne electronics.

The past few years have seen the experimental work of our nation's wind tunnels incline toward the possible performance of guided missiles, etc., in Mach Numbers approaching 8 or 10. Because of these investigations into the higher Mach Numbers, a new subdivision of aerodynamics, Hypersonics, came into being. Appreciating the importance of this new field, the Institute has made arrangements for papers on this subject to be presented at the forthcoming meeting.

Joint Sessions Also Planned

A Session on Flight Safety will again be featured. This will be held in cooperation with The Daniel and Florence Guggenheim Aviation Center at Cornell University.

Joint sessions with other societies have also been planned as a part of the overall program. They include Rotating Wing Aircraft and Meteorology sessions offered by the Institute in cooperation with the American Helicopter Society and the American Meteorological Society, respectively.

Other Fields To Be Discussed

Last year's Annual Meeting marked the first time that a session on Aeroelasticity had been included. Again this year, leading exponents in this field will be heard in a discussion of aeroelasticity and related problems of vibration, flutter, etc.

In addition to the sessions mentioned above are discussions on various phases of Flight Propulsion, Aerodynamics, Supersonics, Structures, and Air Transport.

Time Schedule

Below will be found the time schedule for the Nineteenth Annual Meeting. The Final Program was mailed before the first of the year to the entire I.A.S. membership. Anyone desiring copies may write to: The Secretary, Institute of the Aeronautical Sciences, 2 E. 64th St., New York 21, N. Y.

Time Schedule

Monday, January 29	Tuesday, January 30	Wednesday, January 31	Thursday, February 1
Registration: 8:30 A.M.	Registration: 8:30 A.M.	Registration: 8:30 A.M.	Registration: 8:30 A.M.
Rotating Wing Aircraft Session 9:00 A.M.–12:00 Noon	Supersonics Session 9:00 A.M.–12:00 Noon	Meteorology Session 9:00 A.M.–12:00 Noon	Electronics in Aviation Session—I 9:00 A.M.–12:00 Noon
Flight Propulsion Session 9:00 A.M.–12:00 Noon		Structures Session 9:00 A.M.–12:00 Noon	
	Luncheon 12:30 P.M.	Luncheon 12:30 P.M.	Luncheon 12:30 P.M.
Aerodynamics Session 2:00–5:00 P.M.	Hypersonics Session 2:00–5:00 P.M.	Flight Safety Session 2:00–5:00 P.M.	Electronics in Aviation Session—II 2:00–5:00 P.M.
Honors Night Dinner 7:30 P.M.		I.A.S. Business Meeting 5:00 P.M.	
	Aeroelasticity Session 8:00–11:00 P.M.	Air Transport Session 8:00–11:00 P.M.	

Capt. Delmer S. Fahrney, U.S.N.

Guided-Missile Authority Retires

Captain Delmer S. Fahrney, U.S.N., A.F.I.A.S., retired on November 1 after 31½ years on active duty as a Naval Officer. At the time of his retirement, he was Commander of the Naval Air Missile Test Center, Pt. Mugu, Calif.

Captain Fahrney has been associated with the development of the guided missile during the past 14 years and is considered by the Navy to be its "prime authority in the guided-missile field." Prior to becoming N.A.M.T.C.'s first Commander, he was Director of the Pilotless Aircraft Division, now the Guided Missile Division, Bureau of Aeronautics. In 1936, he was appointed Officer-in-Charge of Radio-Controlled Aircraft and made a study of the problems of this type of craft. That same year, he was assigned to the Naval Aircraft Factory, Philadelphia, as Assistant Chief Engineer in Charge of Radio-Controlled Aircraft Development.

Captain Fahrney and his wife, the former Agnes Whiting Kelly, will reside on their Rondelay Estate, Chadds Ford, Pa.

I.A.T.A. Delegates Guests of Donald W. Douglas

Some 70 delegates to the Sixth Annual General Meeting, International Air Transport Association, were guests of Donald W. Douglas, H.F.I.A.S., President, Douglas Aircraft Company, Inc. The occasion was a symposium held in Los Angeles at which the top engineers at Douglas outlined probable trends in the design of future commercial transports. The I.A.T.A. meeting was concluded in San Francisco on October 20.

After a welcome from Mr. Douglas, Arthur E. Raymond, H.F.I.A.S., Vice-President—Engineering, reviewed the company's technical and transport history. Among those who presented illustrated talks was Carlos Wood, A.F.I.A.S., Preliminary Design Engineer.

A tour of the Douglas plant at Santa Monica followed the meeting and a luncheon. Later in the day, the guests witnessed flight demonstrations of the Navy F3D twin-jet Skynight and the AD-4 Skyraider attack bomber.

1951 International Exhibition

The 1951 Paris International Aircraft Exhibition is to be held June 15–July 1 in the Grand Palais, Champs-Elysées, Paris, France, and at the Paris Airport. Small aircraft, engines, and accessories will be housed in the Grand Palais; larger airplanes are to be shown at the airport. There will also be flying displays. This exhibition is being organized by the Union Syndicale des Industries Aeronautiques and is under the patronage of the French government.

Necrology

John S. Adams, Jr.

John Samuel Adams, Jr., Capt., U.S.A.F., T.M.I.A.S., was killed in an aircraft accident on July 13, 1950. At the time of his death, he was serving on active duty with the 342nd Bombardment Squadron, 97th Bombardment Group, Biggs Air Force Base, Tex.

Born in Oklahoma City on June 30, 1923, Captain Adams was called to active duty in 1943 during his last semester's work at Spartan School of Aeronautics, where his principal study was stress analysis. He became an Aviation Cadet (Ground Duty Engineering) with the U.S. Army Air Corps and was later sent to Yale University for additional engineering training.

Joseph F. Meade, Sr.

Joseph Frederick Meade, Sr., M.I.A.S., President, Mercury Aircraft, Inc., passed away on November 8 in the Bath (N.Y.) Memorial Hospital. He was 58 years old.

A 1917 University of Michigan graduate in Aeronautical Engineering, Mr. Meade was associated with aircraft manufacturing and design during most of his professional career. He joined Aerial Service Corporation in 1924, and, when the corporate name was changed in 1929 to Mercury Aircraft, Inc., he was made its Vice-President and General Manager. Two years later, he became President and General Manager.

He is survived by his widow, Ella; a son, Joseph F., Jr., Vice-President of Mercury; and a daughter, Jeannette E. Meade.

News of Members

▸ **Brigadier General Milton W. Arnold** (A.F.), Vice-President, Air Transport Association, was appointed by the National Security Resources Board to head a Task Group on Air Transportation for the purpose of conducting an air-transport mobilization survey.

▸ **Dr. Daniel P. Barnard, IV** (A.F.), Research Coordinator, Standard Oil Company (Indiana), is scheduled to receive the 1949 Horning Memorial Award at the 1951 S.A.E. Annual Meeting in Detroit. He will receive the award "in recognition of distinguished active service in the field of mutual adaptation of fuels and engines."

▸ **Harold M. Bixby** (H.A.), Vice-President, Pan American World Airways System, was elected a member of the International Air Transport Association's Executive Committee.

▸ **Rear Admiral Calvin M. Bolster,** U.S.N. (H.M.), Assistant Chief for Research and Development, Bureau of Aeronautics, Department of the Navy, was presented with a National Air Council 1950 award for "exercise of extraordinary scientific and engineering skill."

▸ **Robert F. Brodsky** (T.M.) was awarded the degree of Doctor of Science in Engineering by New York University in October. His thesis was concerned with an investigation of the laminar boundary layer. (*See* "Members on the Move.")

▸ **Gordon D. Brown** (A.M.), Owner, Gordon D. Brown & Associates, has moved his company's offices to 407 K Commercial Center St., Beverly Hills, Calif. The factory will remain at 333 N. Foothill Rd., Beverly Hills.

▸ **Donald W. Douglas** (H.F.), President, Douglas Aircraft Company,

DELIVERS CABOT LECTURE

Rear Admiral Calvin M. Bolster, U.S.N. (A.F.), Assistant Chief for Research and Development, Bureau of Aeronautics, was honored by being selected to deliver the ninth in a series of lectures for the James Jackson Cabot Fund, Norwich University. His lecture, "The Assisted Take Off of Aircraft," has been published by the Cabot Fund and is reviewed on page 76 of this issue.

Inc., was presented with a certificate of merit award by the Southern California Financial Writers Association for his outstanding leadership in aviation.

▸ **Carl L. Frederick** (M.), Owner and Manager, Carl L. Frederick & Associates, was recently awarded the degree, Doctor of Science, by his alma mater, Nebraska Wesleyan University. Mr. Frederick is currently Contractor to the U.S.A.F. on Evaluation of Electronic Test Equipment, as well as Expert Consultant, Research and Development Board, Office of the Secretary of Defense.

▸ **Joseph Friedman** (M.), Group Leader, Ram-Jet Combustion Group, Marquardt Aircraft Company, was awarded a Professional Engineering Degree in Chemical Engineering from Cooper Union School of Engineering.

▸ **Arnold M. Kuethe** (F.) returned to his position as Professor of Aerodynamics, University of Michigan, after a year's leave of absence. During that period, he was with the U.S. Air Force as Chief Scientist, Office of Air Research.

▸ **I. M. Laddon** (F.), Director and Consulting Engineer, Consolidated Vultee Aircraft Corporation, was elected to the Board of Directors, Hiller Helicopters.

▸ **Leslie E. Neville** (M.), former Director, Standard Aeronautical Indexing System, and Editor, *Aviation*, has written another book, *Aircraft Designers' Data Book*. Published by McGraw-Hill Book Company, Inc., it presents 788 three-dimensional drawings, plus concise text material, which dramatize features and details of typical foreign and domestic aircraft. It is arranged in eleven chapters corresponding to basic components of the aircraft, such as landing gears, fuel systems, rotating wing aircraft, etc.

▸ **Andre A. Priester** (F.), Vice-President and Chief Engineer, Pan American World Airways System, was appointed to serve until 1952 on the Technical Committee of the International Air Transport Association.

▸ **Delos W. Rentzel** (H.M.), Chairman, Civil Aeronautics Board, was appointed General Chairman of an air-transport mobilization survey undertaken by the National Security Resources Board.

▸ **Robert F. Robinson** (T.M.), Instructor, School of Aeronautics, Purdue University, was elected to the office of National President of Gamma Alpha Rho, a national honorary fraternity for aeronautical engineering. Mr. Robinson, who is a member of the Gamma Chapter, Purdue, was elected at the National Convention on September 29.

▸ **Dr. Hyman Serbin** (M.), Professor of Aeronautical Engineering, Purdue University, has become Consultant on Aerodynamics and Mathematics for Aircraft Armaments, Inc.

▸ **I. Martin Spier** (T.M.), President, Beacon Plastic & Metal Products, Inc., also represents Metal Conversion, Inc., of Brooklyn.

▸ **Willem D. van Zelm** (M.), Consulting Engineer, van Zelm Associates, has become Consultant on Aircraft and Mechanisms for Aircraft Armaments, Inc.

▸ **Gill Robb Wilson** (M.), Columnist, *New York Herald Tribune*, has accepted the Chairmanship of the Aviation Division, 1950 Fund Appeal, Travelers Aid Society of New York.

Members on the Move

This section has been instituted to give information on the latest affiliations of I.A.S. members. All members are urged to notify the News Editor of changes as soon as they occur.

Frank H. Abar, Jr. (T.M.), now Engine Test and Development, Diesel Division, General Motors Corporation.

Elliot L. Adams, Jr. (T.M.), Engineering Department, Boeing Airplane Company. Formerly, Stockman, Bower Roller Bearing Company.

Robert E. Adkisson (T.M.), Designer "B," Douglas Aircraft Company, Inc. Formerly, Draftsman "A," Douglas.

John M. Allison (M.), Head, Engineering Division, Naval Ordnance Experimental Unit, Bureau of Standards,

VICE-PRESIDENT OF NEW FIRM

Joel M. Jacobson (A.F.) resigned this past summer from his position as Director of Technical Engineering and Chief Structural Engineer at The Glenn L. Martin Company to become Vice-President and General Manager of the newly chartered Aircraft Armaments, Inc. The Baltimore engineering offices are under his direct supervision. The objective of this Corporation is the insurance of military superiority of the U.S. Armed Forces by the analysis, development, design, manufacture, and test of practical weapons systems and components that have the maximum effectiveness in terms of destructive power at minimum cost. Mr. Jacobson is Past-Chairman of the Hagerstown and Baltimore Sections of the I.A.S.

ELECTED VICE-PRESIDENT

Roy J. Sandstrom (A.F.) was elected to the position of Vice-President in Charge of Engineering, Bell Aircraft Corporation. He joined Bell in 1938 as Stress Analyst and since has been Project Stress Analyst, Assistant Chief of Stress, Project Engineer, Chief Preliminary Design Engineer, Chief of Technical Services, Executive Chief Engineer. In January, 1950, he was appointed Chief Engineer. Mr. Sandstrom is a member of the Facilities Panel, Research and Development Board.

NAMED BY SPERRY

Norman L. Winter (M.) has been named Director, Special Electronic Sales, Sperry Gyroscope Company, Division of The Sperry Corporation. Mr. Winter came to Sperry in 1949 from the Research and Development Board, where he was Executive Director of the Committee on Electronics. He holds the rank of Colonel, U.S.A.F. Reserve.

BACK WITH BELL

After a year as Engineering Pilot with North American Aviation, Inc., Jean L. Ziegler (M.) has returned to Bell Aircraft Corporation as Chief of Flight Test. He had previously been employed by Bell as a Rocket Engineer. A former Air Force pilot, Mr. Ziegler served with Pan American Airways, Africa, Ltd., on survey work for the Air Transport Command in China and the Middle East. He was once associated with Curtiss-Wright Corporation and was Cofounder, Vice-President, and Director of United Services for Air, Ltd.

APPOINTED CHIEF ENGINEER

Clifford E. Willis (M.) was appointed Chief Engineer, Lear, Incorporated. He has been associated with Lear since 1947, first as Manager, Eastern Offices and later as Assistant Sales Manager, Electro-Mechanical Division. Prior to this time, Mr. Willis was with Fairchild Engine and Airplane Corporation, Aero Engineering, Inc., and Curtiss-Wright Corporation.

Washington, D.C. Formerly, Head, Air Engines Branch, Propulsion Division, Naval Air Missile Test Center, Pt. Mugu, Calif.

Mortimer F. Bates (A.F.), Design Engineer, Research and Development, Guided Missiles, Hughes Aircraft Company. Formerly, Design Engineer, Kollmorgen Optical Corporation.

Thomas F. Bergmann (M.), Manager, Sales Engineering Division, Wright Aeronautical Corporation, Curtiss-Wright Corporation. Formerly, West Coast Sales Engineer, Wright Aeronautical.

D. Bitondo, Ph.D. (T.M.), Aerodynamicist "A," Aerophysics Division, North American Aviation, Inc. Formerly, Graduate Student, Department of Aeronautical Engineering, and Research Assistant, Institute of Aerophysics, University of Toronto, Canada.

John J. Boericke, Jr. (M.), Associate Director, Contracts Division, The Franklin Institute of the State of Pennsylvania. Formerly, Assistant Director, Contracts Division, The Franklin Institute.

Murray A. Brill (T.M.), now Design Engineer Class "A," H. L. Yoh Company, on temporary assignment with Boeing Airplane Company.

Robert F. Brodsky (T.M.), Research Engineer, Sandia Corporation, Albuquerque, N.M. Formerly, Instructor, Mechanical Engineering, New York University. (*See* "News of Members.")

Donald G. Brown (T.M.), Engineering Draftsman "A," Power Plant Division, Missile Department, Douglas Aircraft Company, Inc. Formerly, Student.

Monroe R. Brown (M.), Administrator, Research and Development Division, Piasecki Helicopter Corporation. Formerly, Secretary, Helicopter Council, Aircraft Industries Association.

George H. Buchner (M.), Manager, Contract and Order Department, Propeller Division, Curtiss-Wright Corporation. Formerly, Sales Engineer, Lockheed Aircraft Service, Inc.

Otis J. Cofiniotis (M.), Design Engineer, Lockheed Aircraft Corporation. Formerly, Engineering Designer, Sperry Gyroscope Company, Division of The Sperry Corporation.

Captain James R. Cumberpatch, U.S.A.F. (T.M.), Air Force Project Officer; F-80, T-33, F-94 Aircraft Unit; Directorate, Procurement and Industrial Planning; Headquarters, Air Materiel Command; Dayton, Ohio. Formerly, Student, Graduate Division, Georgia Institute of Technology.

John A. Cunningham (T.M.), now Senior Detailer Grade I, McDonnell Aircraft Corporation.

Commander Robert H. Dasteel, U.S.N. (M.), Bureau of Aeronautics Representative, Pasadena, Calif. Formerly, Assistant Head, Technical Division, Bureau of Aeronautics General Representative (Western District), Los Angeles.

John F. Davis (T.M.), now Design Engineer, A. V. Roe Canada Limited.

James W. Dugan (T.M.), now Engineering Draftsman, Airframe, Lockheed Aircraft Corporation.

Stanley H. Evans (A.F.), now with Project Design Office, Short Brothers and Harland, Ltd., Seaplane Works, Queens Island, Belfast, Northern Ireland.

Edward J. Foley (M.), Eastern Representative, Gordon D. Brown & Associates. Formerly, Assistant to Vice-President, American Airlines System, Washington, D.C.

M. J. Frank (M.), Chief Structural Engineer, Aircraft Armaments, Inc. Formerly, Chief of Laboratories, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation.

Joseph Friedman (M.), Group Leader, Ram-jet Combustion Group, Marquardt Aircraft Company. Formerly, Supervisor, Aerophysics Laboratory, North American Aviation, Inc.

First Lieutenant Roland L. Guerin, U.S.A.F. (T.M.), Assistant Air Installations Officer in Charge of Installations Engineering, 6002 D Installations Squadron, A.P.O. 970, c/o Postmaster, San Francisco. Formerly, Research and Development Project Officer, Headquarters, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio.

C. W. Harris (M.), Assistant Design Administrator, Northrop Aircraft, Inc. Formerly, with Western Design and Manufacturing Corporation.

James C. Hateley (T.M.), with North American Aviation, Inc. Formerly, Engineer, Douglas Aircraft Company, Inc.

Perry O. Hays (T.M.), now A. & E. Mechanic, Capital Airlines, Inc., Mid-Way Airport, Chicago.

Fred W. Henning (T.M.), Development Engineer, Jet Propulsion, Aviation Gas Turbine Division, Westinghouse Electric Corporation. Formerly, Research Engineer, Curtiss-Wright Corporation.

Harold O. Hollenberg (T.M.), Aeronautical Research Engineer, Bureau of Aeronautics. Formerly, Junior Aerodynamics Engineer, The Glenn L. Martin Company.

William T. Immenschuh (M.), Executive Engineer, Ryan Aeronautical Company. Formerly, Project Engineer Ryan.

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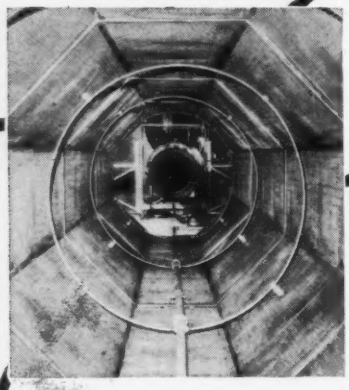

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George Jacobs (T.M.), Engineering Draftsman, Static Test Department, The Glenn L. Martin Company. Formerly, Junior Draftsman, Norden Laboratories Company.

Second Lieutenant John P. Kidner (T.M.), Student Officer, Lackland Air Force Base, Tex. Formerly, Student.

First Lieutenant Robert B. Kleinman, AO-822192, U.S.A.F. (T.M.), 610 Aircraft Control and Warning Squadron, A.P.O. 929-3, c/o Postmaster, San Francisco. Formerly, Pilot, U.S.A.F. Electronics School, 3380 Training Squadron, Keesler Air Force Base, Miss.

Joseph T. Lester, Jr. (T.M.), Research Engineer, Naval Supersonic Laboratory, Massachusetts Institute of Technology. Formerly, Mechanical Engineer, Self-Locking Carton Company.

George N. Mangurian (M.), Chief Structural Engineer, Northrop Aircraft, Inc. Formerly, Project Structural Design Engineer, The Glenn L. Martin Company.

Russell J. McCrea (M.), Executive Director, Panel on Facilities, Committee on Aeronautics, Research and Development Board, Office of the Secretary of Defense. Formerly, Aerodynamics Engineer, Fort Worth Division, Consolidated Vultee Aircraft Corporation.

Byron D. Miller (T.M.), now Analyst "B," Flight Test Department, Fort Worth Division, Consolidated Vultee Aircraft Corporation.

Albert Mooradian (T.M.), Designer, The Kaman Aircraft Corporation. Formerly, "A," Layout, The Glenn L. Martin Company.

Captain Joseph N. Murphy, U.S.N. (A.F.), Commander, U.S. Naval Air Missile Test Center, Pt. Mugu, Calif. Formerly, Manager, Naval Aircraft Factory, N.A.M.C., Naval Base, Philadelphia.

Lieutenant Commander James W. Neighbours, U.S.N. (M.), Overhaul and Repair Department, Naval Air Station, Seattle. Formerly, M.A.T.S., Navy 128, Fleet Post Office, San Francisco.

Roy T. Nilsen (M.), Design Engineer, Engineering Department, McDonnell Aircraft Corporation. Formerly, Staff Engineer, Structures and Controls, United Air Lines, Inc.

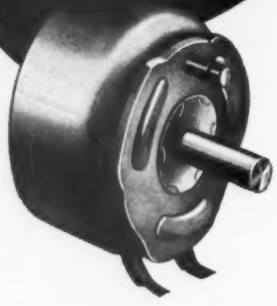
Joseph P. Paine (M.), Chief Electro-Mechanical Engineer, Aircraft Armaments, Inc. Formerly, Chief Structural Dynamics Engineer, The Glenn L. Martin Company.

Paul H. Peck (T.M.), Project Engineer and Technical Writer, Jackson and Moreland, New York and Boston. Formerly, Application Engineering Data Editor, The Foxboro Company, Mass.

Commander J. Parke Sager, U.S.N. (T.M.), Office of Bureau of Aeronautics General Representative, Central District, Wright-Patterson Air Force Base, Dayton, Ohio. Formerly, Overhaul and Repair Department, Production Division, Naval Air Station, Alameda, Calif.

F. Robert Schmidt (T.M.), Rocket Test Engineer, Bell Aircraft Corporation. Formerly, Graduate Student.

LEDEX
ROTARY SOLENOID



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We supply to quantity users and solicit the opportunity to be of assistance in engineering a Ledex Rotary Solenoid to meet your product's requirements.

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Diameter	1⅛"	1⅞"	2¼"	2¾"	3⅜"
Torque lb./inches	¼	5	10	25	50
Weight lbs.	⅛	½	1	2¼	4¼

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Colonel Marvin Sledge, U.S.A.F. (T.M.) now in Korea. Formerly, Plant Representative, Allison Division, General Motors Corporation.

Lee H. Smith (M.), now Customer Field Service Manager, Northrop Aircraft, Inc.

Marvin Stern (T.M.), Mathematics Consultant, Aerodynamics Department, Republic Aviation Corporation. Formerly, Senior Stress Analyst, Republic.

James L. Straight (A.M.), Administrator, The RAND Corporation. Formerly, Assistant Director, Institute of the Aeronautical Sciences, Los Angeles.

Dr. Victor G. Szebehely (M.), Associate Professor of Research and Research Director, Applied Mechanics Department, Virginia Polytechnic Institute. Formerly, Assistant Professor of Applied Mechanics, V.P.I.

Richard B. Trefny (T.M.), now Graduate Student in Aeronautics, University of Washington.

John E. Turner (T.M.), now Engineer, Douglas Aircraft Company, Inc.

John A. Wallace (T.M.), now Stress Analyst, Grumman Aircraft Engineering Corporation.

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*. Responsibility for new developments, awards or honors received, and appointments to new or additional positions are some of the items that your editors believe are of interest to other I.A.S. Members. A brief letter or postal card giving *exact* details will be sufficient. Photographs accompanying news items will be welcomed and will be used where practicable.

Items submitted will be considered on the basis of their timeliness and general interest. Correspondence should be addressed to the News Editor, *Aeronautical Engineering Review*, 2 East 64th Street, New York 21, N.Y.

Ricardo F. Wallace, Jr. (T.M.), now Engineering Trainee, North American Aviation, Inc.

W. J. Werback (T.M.), Hydrodynamics Engineer, Consolidated Vultee Aircraft Corporation. Formerly, Student.

H. Dudley Wright (A.M.), Head, Wright Engineering Company, Pasadena, Calif. Formerly, with G. M. Giannini & Company.

Raymond W. Young (M.), Vice-President in Charge of Engineering, Reaction Motors, Inc. Formerly, Vice-President of Engineering, Wright Aeronautical Corporation.

Captain Samuel J. Zeigler, Jr., U.S.N. (Ret.) (M.), Eastern Engineering Representative, Solar Aircraft Company, Washington, D.C. Formerly, Chief Engineer, Solar's Des Moines Plant.

Corporate Member News

• **Aeroquip Corporation . . .** The Board of Directors authorized an expansion program for the plant of Aero Coupling Corporation, a wholly owned subsidiary.

• **Airborne Accessories Corporation . . .** Models R-430 and R-440 "Rotorette" are adaptable to valve operation and similar applications. Weighing approximately 1 lb., these electric rotary actuators feature load-limiting switches that may be adjusted to any value up to 50 lb.-in. The motion between travel limits is controlled by adjustable positive stops that cause a reaction on the load-limit switches.

• **Aircraft Radio Corporation . . .** A signal generator for complete testing of V.H.F. air-borne omnirange and localizer receivers in aircraft or on the bench has been introduced. The unit, designated as Type H-14, has a frequency range of 108–118 megacycles and provides facilities for testing 24 omnicourses, plus left-center-right checks on both amplitude and phase localizers. Radio-frequency output for ramp checks is 1 volt into 52-ohm line; for bench checks, 0 to 10,000 microvolts.

• **AiResearch Manufacturing Company, Division of The Garrett Corporation . . .** The early model 049 Constellations, owned and operated by Trans World Airlines, Inc., is being equipped with the most advanced pressurization equipment. This includes the major units of the cabin-pressure system—viz., cabin superchargers, cabin-pressure regulators, and other vital supplementary controls. This work by AiResearch is an important part of T.W.A.'s program to convert the 57-passenger transports into 81-passenger Skycoaches.

• **Al Fin Division, Fairchild Engine and Airplane Corporation . . .** Rights in Germany for the use of the Al-Fin process of molecularly bonding aluminum to ferrous metals have been granted to Metallgesellschaft, A.G., of Frankfurt am Main. Through the license agreement, Metallgesellschaft obtained rights to use the process in its own plants and to issue sublicenses to other German firms.

• **Boeing Airplane Company . . .** New electronic analog computers capable of solving the lateral and longitudinal rigid-body flight equations of an airplane and its control-surface actuators simultaneously was designed and built by the company. It is being used to solve dynamic problems in five of the company's engineering research units. . . More than $7,500,000 from its earnings is being spent or committed this year for additional research. . . The prototype Stratocruiser, initially flown on July 8, 1947, was acquired by Pan American. This prototype is the first of 56 sister ships built for the United States and foreign air lines. All interior furnishings and pressurization equipment are to be installed by Pan American.

• **Consolidated Vultee Aircraft Corporation. . .** The double-decker XC-99 military transport flew 200,000 ton-miles on its first operational mission in an extensive evaluation program at Kelly Air Force Base, Tex. Delivered to the Air Force in May, 1949, it was sent to Kelly A.F.B. for modification, including installation of six 3,500-hp. engines. Take-off gross weight on some of the XC-99's flights has been over 300,000 lbs. . . High-altitude bomb drops from B-36 bombers during test flights are under way at the Fort Worth Division Some of the dummy bombs weigh as much as 12,000 lbs. and are dropped from approximately 8 miles up. As the bombs are released, an electrical impulse from the ship to the ground automatically starts cameras located around the target area. These cameras follow the bomb until it hits the ground. . . Two additional bunks are being installed in the forward cabin of the B-36. Earlier model B-36's had only six bunks, all in the aft cabin. The two new ones are being installed in the radio operator's compartment and in the navigator's compartment. . . The Fort Worth Division is well into a subcontracting program under which approximately one-fourth of the basic B-36 bomber will be built by subcontractors.

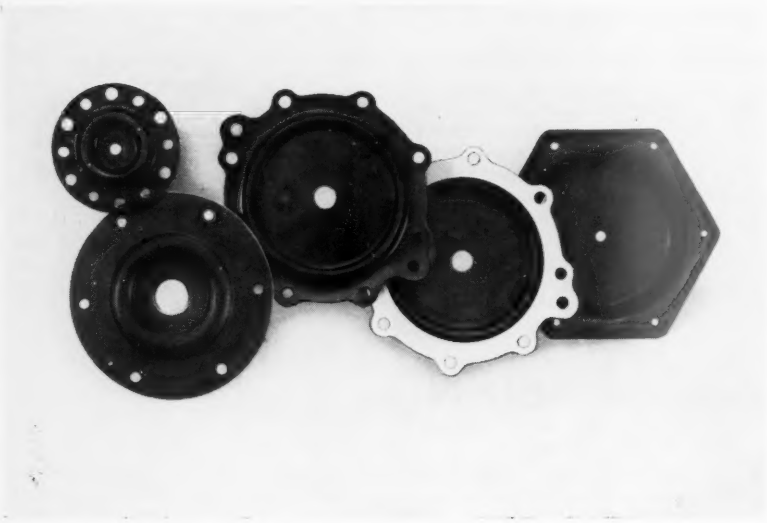
• **Cornell University . . .** An "engineering project plan" has been placed in operation on a college-wide basis in the College of Engineering. This program requires each student to complete an individual problem of specific research as a part of his final year's work in the five-year undergraduate curriculum.

• **Curtiss-Wright Corporation . . .** The Propeller Division has put out a booklet describing the *Curtiss Turbolectric Propellers for Turbo-Prop Engines.*

• **Esso Standard Oil Company . . .** A new booklet, *Quenching and Tempering Oils*, is available gratis. The booklet is designed to provide the background material for evolving an efficient and economical quenching system suited to the individual need.

• **Fairchild Camera & Instrument Corporation . . .** A new production Data Recording Camera was developed from a

DIAPHRAGMS
Industry's Rubber Lungs



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basic design by North American Aviation, Inc. This 35-mm. camera has been subjected to tests throughout a temperature range of −60° to +160°F., at accelerations up to 12*g*, and at altitudes ranging from 0 to 60,000 ft. The unit includes remote selection of four to 16 frames per sec., with constant exposure rate regardless of frame speed. Power requirements are 28 or 110 volts, optional.

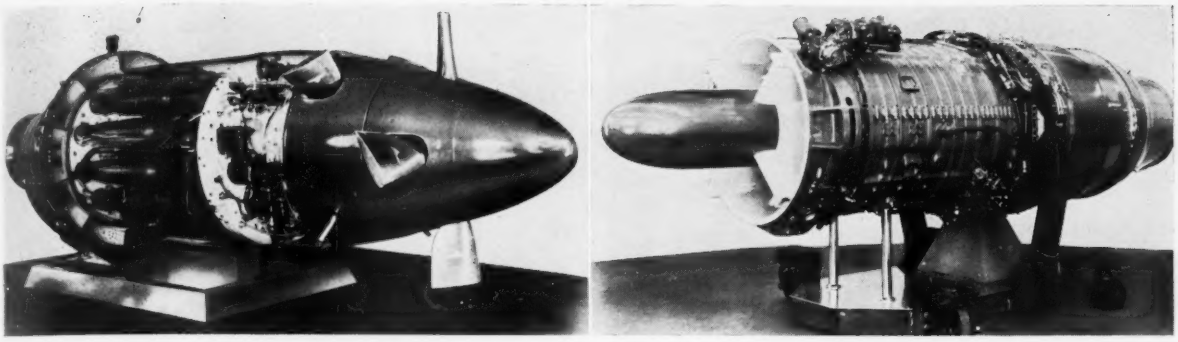
• **General Electric Company . . .** The new measurements laboratory of the Meter and Instrument Divisions was officially opened at Lynn, Mass., on October 30. Said to be the most modern and best equipped of its kind in the world, the new laboratory is staffed by engineering specialists in magnetism, electricity, chemistry, metallurgy, sound, heat, light, and color and contains complete facilities for applied-research product development and design in the field of measurements. . . A new silicone-insulated portable a.c. welder, equipped with an automatic "Hot Start" control, has been announced. Known as 6WK30J series, it is one of the first standard a.c. welder lines commercially available incorporating silicone insulation. . . Bulletin GEA-5537, *Longer Ranges, Heavier Payloads*, is available. The bulletin discusses in detail G-E's new CH9 turbosupercharger.

• **General Electric Company, Aircraft Gas Turbine Division . . .** Jet-engine manufacturing facilities at Lockland, Ohio, are being expanded. The company plans to procure additional factory space there and to move its executive and engineering staffs from Lynn, Mass., to Lockland. No other shifts are contemplated.

• **The B. F. Goodrich Company. . .** Replacement or repair of aircraft aileron and tail surfaces is said to be speeded by the use of a Pressure Sealing Zipper which forms an airtight, separable joint on the fabric flap used as a seal between these movable surfaces. The aileron, elevator, or rudder of any airplane can be installed on another airplane of the same design because the zippers are interchangeable. The zipper is currently used on the B-36, the B-47, and the P2V. One-half of the zipper is permanently attached to the structure of the airplane; the other half is cemented or sewn to the fabric flap that is permanently attached to the leading edge of the aileron or elevating surface. Overlapping rubber lips covering the zipper's metal teeth provide a seal against gases and liquids. . . An airplane fuel cell, holding 2,500 gal., has been built for the Boeing B-47 jet bomber. It measures 8 ft., 9 in. long; 8 ft., 1 in. wide; and 7 ft. high.

• **Jack & Heintz Precision Industries, Inc. . . .** A new generator, designed to Navy specifications primarily for ground-power use, has a rating of 500 amp., 30 volts d.c., has a speed range 4,000–8,000 r.p.m., and weighs less than 80 lbs., with an overall length from the mounting flange of 13 in. Its standard 11-in. diameter, 10-in. bolt circle-mounting flange fits the A.N.D. 20006 standard pad. The generator proper has a diameter of $9^{27}/_{32}$ in.

• **Lear, Incorporated . . .** A new line of high-speed, lightweight, 26-volt, d.c. motors is available in continuous duty models with rated outputs of 0.5 hp. and intermit-



WRIGHT EXPANDS PRODUCTION LINE

Under a long-term engineering and production agreement with Armstrong Siddeley Motors, Ltd., of England, the Wright Aeronautical Corporation, Division of Curtiss-Wright Corporation, has added a new series to its line of engines. This series includes the Sapphire (right) and the Python (left) as well as the Mamba and Double Mamba (not shown). The Sapphire, one of the world's most powerful turbojet engines, has a rated static thrust of 7,220 lbs., a weight of 2,518 lbs., and a diameter of 37 1/2 in. Its axial-flow compressor flight testing in a Lancastrian began in January, 1950. The Python, among the most powerful turboprop engines, is rated at 4,000 equivalent s.hp. It weighs 3,400 lbs., has a diameter of 53 in. and has two coaxial propeller shafts. The Double Mamba is a turboprop engine with a 2,873 equivalent s.hp. rating and weighs 2,000 lbs. The Mamba, the "baby" of the turboprops, is rated at 1,450 equivalent s.hp., weighs 780 lbs., and has a diameter of 29 in. All four engines in this series have passed their 150-hour type tests and have been successfully flown.

tent-duty models with rated outputs to 2 hp.

• **The Glenn L. Martin Company . . .** An economical wind-tunnel balance that measures simultaneously all six basic windage components—three moments and three forces—has been developed. The M-6-C Balance weighs scarcely 3 lbs. Cylindrical in form and less than 10 in. long, the device is installed inside the missile or aircraft model to be tested. This device permits each of the six components to be read directly off dials in the control room.

• **North American Aviation, Inc. . . .** The latest version of the Sabre, the F-86E, incorporates an "all-flying" tail, "artificial feel" system, and "irreversible control" system. The horizontal stabilizers and elevators are linked for coordinated movement. As none of the actual air loads, or forces, act on the stick, an "artificial feel" was designed to give the pilot a representative "feel" of the control forces. The "flying tail" and ailerons are held at given settings, as positioned by the pilot, through an "irreversible control" system. A pressure-sensing unit built into the "irreversible control" system warns the pilot through added force on his stick. This added force increases the "artificial feel" force when the longitudinal control is threatened by excessive air loads on the "flying tail.". . . The AJ-1 attack bomber with an empty weight of 17 tons has successfully completed trial landings aboard the aircraft carrier U.S.S. "Coral Sea." The AJ-1 is powered by two Pratt & Whitney R-2800 reciprocating engines, developing 2,300 hp. each, and a single Allison J-33 turbojet with a thrust in excess of 4,000 lbs. The outer wing panels of the AJ-1 fold inboard, and the vertical tail folds onto the right surface of the horizontal stabilizer for ease of carrier handling. . . An agreement has been signed with Curtiss-Wright Corporation transferring the operation of the Naval Industrial Reserve Aircraft plant at Port Columbus, Ohio, to North American. Curtiss-Wright closed the plant on November 24, and North American reopened it on December 4. Plans called for all C.-W. employees to be terminated by C.-W. and to report to North American as new employees.

• **Pan American World Airways, Inc. . . .** The 23rd anniversary was observed on October 28. On that date in 1927, P.A.A. started flying between Key West and Havana and carried only a two-man crew and a few bags of mail in a trimotored Fokker. . . With the C.A.A. approval of voice communications between in-flight clippers and radio ground stations on the Basra–Karachi–New Delhi of the far eastern route, Pan American has completed its round-the-world radio-telephone system.

• **The Parker Appliance Company. . .** A 48-page, O-ring Catalog 903 has been published and is available on request.

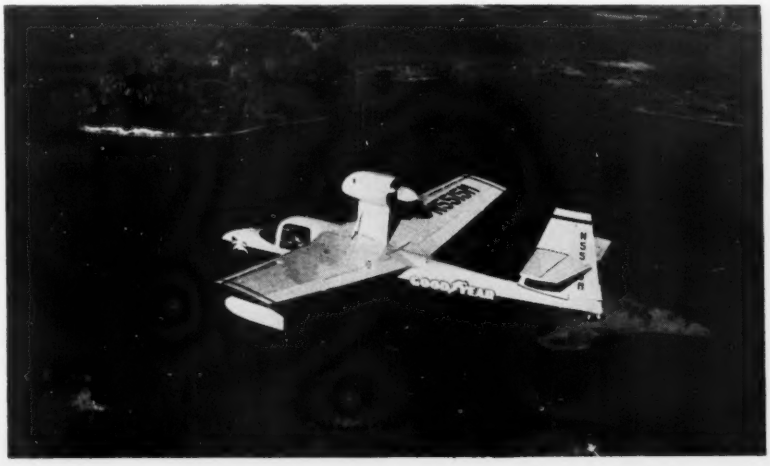
• **Piasecki Helicopter Corporation . . .** The HUP-1 is scheduled to be the first Navy production helicopter equipped with automatic-pilot controls.

• **Pratt & Whitney Aircraft Division, United Aircraft Corporation . . .** A two-story waste-disposal plant is being constructed to help purify the waters of the Connecticut River from industrial waste and sewage. Waste fluids from the production and experimental areas of both P. & W. and Hamilton Standard divisions will be subjected to a chemical process of purification in the new plant.

(Continued on page 84)

PROTOTYPE AMPHIBIAN

Goodyear Aircraft Corporation of The Goodyear Tire & Rubber Company has developed an experimental four-place all-metal amphibian, the GA-22, powered by a single pusher-mounted 186-hp. engine. The GA-22, an offshoot of the three-place GA-2, is adaptable to all-passenger or all-cargo pay loads. It may be converted to litter-carrying for rescue missions from either land or water.



A Guest Editorial

Youth Must Be Served

Excerpts from an Address Given at an Institute Dinner in Philadelphia on 26 October, 1950

". . . A review of the complete list of titles of papers published in the JOURNAL OF THE AERONAUTICAL SCIENCES impresses one with the infinite scientific study being expended on the airplane and its immediate environment. I doubt that any device in common use has ever been analyzed so exhaustively or is enjoying a more scientific approach to its future design. In this respect, the boundary between science and engineering becomes fuzzy, but this is a good thing. If this boundary will just remain fuzzy enough so that the young engineer will be slightly scientific and the young scientist will be moderately tainted with engineering, this country ought to have some good flying machines. If the boundary between science and engineering does not remain fuzzy, we will see such spectacles again as science scaring the daylights out of engineering by such things as 'sonic barriers.' After all, this was not so tough, once the engineers really recovered their common sense and a pilot, who may or may not have been either a scientist or engineer, just flew through the dreaded zone.

"Here I should like to get in my usual plug. Advisedly, I spoke of the *young* scientist and the *young* engineer. My contemporaries, out of whose ranks have emerged the distinguished, and sometimes stuffy, elders of aeronautical science and aeronautical engineering, are beyond hope. My generation was raised in an atmosphere in which the scientist was venerated in a tolerant sort of way but as a creature apart from the utilitarian world. The engineer, on the other hand, given a Marks' *Handbook* and a drafting kit, could design anything desired by man and with no theoretical foolishness about it, either. Only that which was 'practical' and easily understood was desired by us, until science slapped us in the face with something like wireless. And since the advent of wireless there have been so many more scientific developments thrust upon us that the older engineer has lost much of his cocksureness and the older scientist has become intoxicated by his own influence and has abandoned his hallowed role to descend into the earthly fields of fiscal administration.

by

Rear Adm. A. M. Pride, U.S.N.

Chief of the Bureau of Aeronautics

"Neither transformation has been very edifying to those of us lesser mortals who are neither scientists nor engineers but who were brought up to maintain both groups on high pedestals. Traditionally, we prefer our clergy and our doctors and our scientists and our engineers in consecrated and neatly compartmented fields of endeavor. But such compartmentation will no more produce the best flying machines than it will produce the best wireless sets.

"The scientist must become the engineer, on occasion, and the engineer must reach up into the regions of science. This departure from the traditional can only be accomplished by youngsters, and it is a wonderful thing to see that youngsters are doing it.

"Although I cannot comprehend the contents of papers submitted to the JOURNAL, I can see that I have never heard of many of the authors, and this is a wonderful thing. It means that the Institute is providing a broad avenue for the expression that is so essential to the generation of new ideas. But, even more important, it means that the youngsters upon whom the future of this civilization depends, are making themselves heard and are taking over from those of the generation that seems to have made such an unholy mess of things.

"I would not wish to imply for one moment, that the Institute of the Aeronautical Sciences should become a Youth Movement for the advancement of precocious scientific brats. Rather, I applaud, most sincerely and enthusiastically, the Institute's apparent policy of welcoming and publishing advanced, and what I hope are unorthodox, ideas. This is being truly liberal and constructive in the best senses of these words.

"May the Institute prosper down through the years under its enlightened policy. And when today's youngsters have become graybeards and have thoroughly botched up the affairs of their generation, as mankind can be relied upon to do, may they have the good grace, and common sense, to dust off this policy and respect and publish the views of their youngsters.

"If they will, maybe the human race will get somewhere someday. . . . ."

A Design Method for Automatic Longitudinal Control Systems

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ABSTRACT

This paper presents a new approach to the problem of designing intercoupled multiloop control systems. Of general application to the treatment of a large class of such intercoupled systems, this method is of particular value in the design of automatic longitudinal control systems for aircraft. The method is developed in terms of this specific application and is illustrated by the design of a fully automatic air-speed-altitude control for the Northrop F-61C airplane. By satisfying the requirement that thrust and pitch attitude be controlled in coordination, the method allows separate design of the air-speed and altitude control functions. The effectiveness of the design is substantiated by transient response solutions obtained in simulation of the system with an electronic analog computer.

SYMBOLS

x = craft axis, passing through c.g. and directed along steady-state wind. Positive forward

y = craft axis, passing through c.g., perpendicular to x-axis and horizontal in level flight. Positive to right

z = craft axis, passing through c.g., perpendicular to x- and y-axes. Positive downward

X, Y, Z = force per unit mass along x-, y-, and z-axes, ft. per sec.^{2}

M = moment per unit moment-of-inertia about y-axis, deg. per sec.^{2}

u = change in craft velocity along x-axis, ft. per sec. Positive forward

u_e = air-speed error ($u - u_0$)

u_0 = change in control system air-speed reference

w = change in craft velocity along z-axis, ft. per sec. Positive downward

h = change in altitude, ft.

h_e = altitude error ($h - h_0$)

h_0 = change in control system altitude reference

g_{Tu} = control system transfer function expressing dynamic relationship between applied thrust and measured air-speed error, lbs. per ft. per sec.

g_{Th} = control system transfer function expressing dynamic relationship between applied thrust and measured altitude error, lbs. per ft.

g_{Iu} = control system transfer function expressing dynamic relationship between applied autopilot pitch bias and measured air-speed error, deg. per ft. per sec.

g_{Ih} = control system transfer function expressing dynamic relationship between applied autopilot pitch bias and measured altitude error, deg. per ft.

A_θ = pitch autopilot static gain, deg. elevator per deg. pitch error

G_θ = pitch autopilot mixer transfer function (accounts for effect of rate network)

ω_a = pitch autopilot natural frequency, rad. per sec.

ζ_a = pitch autopilot damping ratio

θ = change in pitch angle (rotation about y-axis), deg. Positive for nose up

δ_e = elevator angle, deg. Positive upward

T = change in thrust, lbs.

I = biasing pitch input to autopilot, deg.

f_{uT} = craft transfer function expressing dynamic effect of thrust upon forward velocity with I constant, ft. per sec. per lb.

f_{uI} = craft transfer function expressing dynamic effect of autopilot pitch bias upon forward velocity with T constant, ft. per sec. per deg.

Δ = determinant made up of the coefficients of the variables u, sh, and θ in the stability equations of the craft with pitch autopilot engaged

Δ_{ux} = minor of the u-column, x-row of the determinant, Δ. Other minors are defined similarly for the h- and θ-columns and for the Z- and M-rows

X_u, X_w, Z_w, M_θ, etc., $\frac{\partial X}{\partial u}$, $\frac{\partial X}{\partial w}$, $\frac{\partial Z}{\partial w}$, $\frac{\partial M}{\partial \theta}$, etc. = aerodynamic stability derivatives

INTRODUCTION

THE HUMAN PILOT IS an important element of present conventional automatic pilots. During constant-altitude flight, the pilot must regulate air speed by manual throttle adjustment. During climb or descent, the two functions of throttle regulation and pitch control must be performed manually. The longitudinal control system serves only to maintain pitch stability. With the increasing importance of automatic landing systems and of pilotless aircraft, there is need for a means by which air speed and altitude may be controlled directly and automatically without the necessity of a human pilot to interpret air-speed and altitude errors into pitch and throttle adjustments.

The design of an automatic system capable of controlling air speed and altitude is complicated by the fact that changes in thrust and changes in pitch attitude each affect both air speed and rate of climb. A design is developed in this paper in which one function of the control system is to separate the control of altitude from the control of air speed through coordination of pitch and thrust. The remainder of the two intercoupled loops are then designed by conventional single-loop design methods.

FUNCTIONAL EQUATIONS

A typical multiloop longitudinal control system to be designed is illustrated in Fig. 1. The terms u_0 and h_0 are changes in desired air-speed and altitude functions

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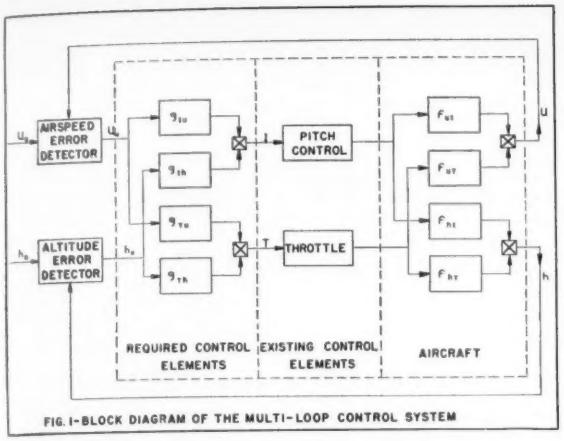

FIG. 1-BLOCK DIAGRAM OF THE MULTI-LOOP CONTROL SYSTEM

and appear in the system as mechanical rotations of synchro shafts. The terms u and h are changes in manometric air speed and pressure altitude as observed by aneroid instruments equipped with induction pickoffs. u_ϵ and h_ϵ are signals representing the difference between prescribed craft motion (u_0 and h_0) and the existing craft motion (u and h) and are the inputs to the control system. The elements appearing in the section labeled "Required Control System" are to be designed. Those in the boxes titled "Aircraft" and "Existing Control Elements" include the characteristics of the air frame, power plant, and autopilot and are considered unalterable for this analysis.

Consider an airplane flying at equilibrium with constant-pitch attitude and constant thrust. If the thrust is changed by an amount T, there follows transient change of both air speed, u, and altitude, h, until new steady-state conditions of air speed and rate of climb are established. If pitch reference is changed by an amount I (input to autopilot pitch channel), a different transient change to new steady-state conditions of air speed and rate of climb results. These facts are stated symbolically in the craft functional equations:

$$\left.\begin{aligned} u &= f_{uI}I + f_{uT}T \\ h &= f_{hI}I + f_{hT}T \end{aligned}\right\} \qquad (1)$$

where f_{uI} is a transfer function relating the acting change of pitch reference, I, and the resulting change of air speed, u. The other f terms are similarly defined. They are ratios of polynomials in the Laplacian operator s, depending only upon the aircraft and the existing control elements, and are obtained from the combined aircraft-autopilot system differential equations as shown in Appendix 1. The control system may be represented by a similar pair of equations:

$$\left.\begin{aligned} I &= g_{Iu}u_\epsilon + g_{Ih}h_\epsilon \\ T &= g_{Tu}u_\epsilon + g_{Th}h_\epsilon \end{aligned}\right\} \qquad (2)$$

The terms of g are transfer functions of required control system elements; for example, g_{Iu} transforms a measured error in air speed into a pitch signal to the autopilot.

The design of these g terms, the control system elements, is the subject of this investigation.

Separation of Air-Speed and Altitude Control

The basis for conventional control system design is the open-loop transfer function. The open-loop transfer functions of interest in the present problem are the ratios u/u_ϵ and h/h_ϵ. The first step toward obtaining these ratios is made by eliminating T and I between Eqs. (1) and (2):

$$\left.\begin{aligned} u &= (f_{uI}g_{Iu} + f_{uT}g_{Tu})u_\epsilon + (f_{uI}g_{Ih} + f_{uT}g_{Th})h_\epsilon \\ h &= (f_{hI}g_{Iu} + f_{hT}g_{Tu})u_\epsilon + (f_{hI}g_{Ih} + f_{hT}g_{Th})h_\epsilon \end{aligned}\right\} \qquad (3)$$

Eqs. (3) indicate that, in general, change of air speed is a function of both air-speed error and altitude error inputs to the control system. As Eqs. (3) stand, it is not possible to write an open-loop transfer function for air-speed control until the altitude control has been designed; nor is it possible to write an open-loop transfer function for altitude control without knowledge of the air-speed control design.

Notice that there are four control system transfer functions to be designed but only two variables to be controlled. This suggests that an arbitrary restriction may be placed upon each of the two pairs of control system elements. In the case of air speed, an extremely useful result is obtained by requiring that the system control thrust and pitch be in coordination so that an air-speed error acts to change air speed without affecting altitude—in other words, require that the control system design eliminate the unwanted terms in Eqs. (3):

$$\left.\begin{aligned} f_{uI}g_{Ih} + f_{uT}g_{Th} &= 0 \\ f_{hI}g_{Iu} + f_{hT}g_{Tu} &= 0 \end{aligned}\right\} \qquad (4)$$

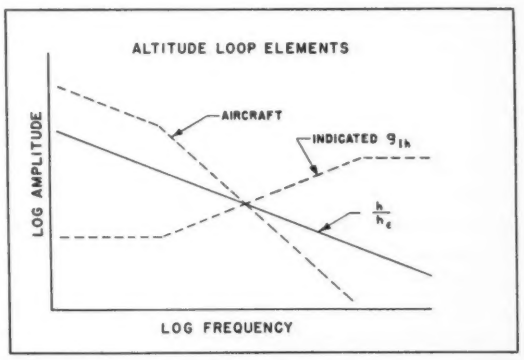

FIG. 2

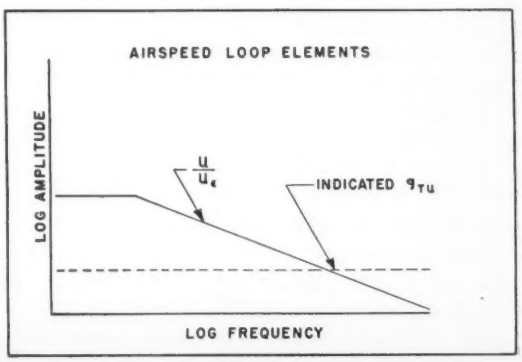

FIG. 3

TABLE 1

F-61C Longitudinal Coefficients

Flight Condition	(a)	(b)	(c)	(d)	(e)	(f)
H (ft.)	10,000	10,000	10,000	25,000	25,000	25,000
V_M (m.p.h.)	171	200	229	167	190	213
U_0 (ft./sec.)	293	343	393	368	418	468
X_u (sec.$^{-1}$)	−0.0174	−0.0203	−0.0232	−0.0088	−0.0100	−0.0112
X_w (sec.$^{-1}$)	+0.0521	+0.0610	+0.0698	+0.0587	+0.0668	+0.0750
X_θ [(ft.) (sec.)$^{-2}$ (deg.)$^{-1}$]	−0.293	−0.196	−0.082	−0.183	−0.073	−0.052
X_T [(ft.) (sec.)$^{-2}$ (lb.)$^{-1}$]	+0.00115	+0.00115	+0.00115	+0.00115	+0.00115	+0.00115
Z_u (sec.$^{-1}$)	−0.168	−0.255	−0.292	−0.274	−0.312	−0.350
Z_w (sec.$^{-1}$)	−0.831	−0.972	−1.11	−0.631	−0.718	−0.805
Z_θ[(ft.) (sec.)$^{-2}$ (deg.)$^{-1}$]	−4.24	−5.82	−7.63	−4.06	−5.24	−6.58
M_w[(deg.) (sec.)$^{-1}$ (ft.)$^{-1}$	−0.720	−0.842	−0.964	−0.544	−0.619	−0.694
$M_{\dot\theta}$ (sec.$^{-1}$)	−1.91	−2.23	−2.55	−1.45	−1.65	−1.85
$M_\delta A_\theta$ (sec.$^{-2}$)	−6.50	−6.50	−6.50	−6.47	−6.47	−6.47

Making use of the restrictions stated in Eqs. (4), it is possible to write Eqs. (3) in the desired form of open-loop transfer functions:

$$\left.\begin{aligned} \frac{u}{u_e} &= \frac{f_{uT}f_{hI} - f_{uI}f_{hT}}{f_{uT}f_{hI}} f_{uT}g_{Tu} \\ \frac{h}{h_e} &= \frac{f_{uT}f_{hI} - f_{uI}f_{hT}}{f_{uT}f_{hI}} f_{hI}g_{Ih} \end{aligned}\right\} \qquad (5)$$

Note that each transfer function contains only one control system element. That element is subject to design by any of the existing methods of control system synthesis. g_{Tu} and g_{Ih} are designed on the basis of Eqs. (5) to satisfy requirements of control stability and accuracy. g_{Iu} and g_{Th} must then be chosen to satisfy the relations of Eqs. (4).

Application to Control of the F-61C Airplane

Eqs. (4) and (5) indicate the theoretical possibility of independent control of altitude and air speed through the coordination of pitch and thrust. The coordinating restriction impressed by Eqs. (4) greatly simplifies the design process, since the system is reduced to two isolated systems, each described by the transfer function relationship of Eqs. (5). Briefly, the design method is as follows:

(1) Obtain the terms in Eqs. (5) which are known functions of the aircraft and autopilot. Eqs. (5) are plotted as approximate steady-state frequency response curves in Figs. 2 and 3.

(2) Select g_{Tu} and g_{Ih} from considerations of stability and transient response.

(3) Substitute g_{Tu} and g_{Ih} in Eqs. (4) to obtain the transfer functions describing g_{Th} and g_{Iu}.

(4) Design four networks to provide the frequency characteristics required by the four control system transfer functions.

In the particular application for which this design was performed, the F-61C airplane is required to conform accurately to steady or slowly changing air-speed and altitude references. Consequently, static accuracy and stability are emphasized over time of response. The design is based on a system cutoff frequency of 0.2 rad. per sec., so that any factor whose influence is felt only at frequencies above 2 rad. per sec. is assumed negligible. Primary system parameters are selected for the flight condition 190 m.p.h. at a 25,000-ft. altitude. The effects of other speeds and altitudes are then considered, and a suitable compromise is selected.

Altitude Control

For the F-61C, the altitude control forward-loop transfer function is obtained by using the open-loop transfer function derived in Appendix 2 and the stability derivative values of Table 1:

$$\frac{h}{h_e} = \frac{7.3}{s(1 + 2.4s)} g_{Ih}$$

The factor $1/s$ represents integration of altitude error and is desirable from the standpoint of static accuracy. However, it is desirable to compensate for the factor $1/(1 + 2.4s)$ by a lead network in g_{Ih}. This suggests the form $g_{Ih} = K_{Ih}(1 + 2.4s)$. In order to provide a 0.2 rad. per sec. cutoff frequency, the value of K_{Ih} is found to be 0.028 deg. pitch reference per ft. altitude error.

Having a tentative value for g_{Ih}, Eqs. (4) may be examined to find the remaining altitude control component g_{Th}. Numerical substitution gives

$$\begin{aligned} g_{Th} &= [500/(1 + 2.4s)]g_{Ih} \\ &= 14 \text{ lbs. thrust per ft. altitude error} \end{aligned}$$

Both g_{Ih} and g_{Th} are seen to require simple networks so that the mechanization of the altitude control system is routine.

Air-Speed Control

The nature of the air-speed control forward loop is shown graphically in Fig. 3. The open-loop transfer function is

$$\frac{u}{u_e} = \frac{0.20}{1 + 180s} g_{Tu}$$

Since this form is satisfactory as it stands, g_{Tu} is chosen a constant. A 0.2 rad. per sec. cutoff frequency is provided by the value g_{Tu} = 170 lbs. thrust per ft. per sec. air-speed error.

The relation between g_{Iu} and g_{Tu} obtained from Eqs. (4) is

$$\begin{aligned} g_{Iu} &= [0.021/(1 + 180s)]g_{Tu} \\ &= [3.5/(1 + 180s)] \text{ deg. pitch per ft. per sec. air-speed error} \end{aligned}$$

TABLE 2

Effect of Flight Conditions upon Control Relations

Flight Condition	g_{Th}/g_{Ih}, Lbs. per Deg.	Altitude Loop Gain Based upon Condition (e)	g_{Iu}/g_{Tu}, Deg. per Lb.	Airspeed Loop Gain Based upon Condition (e)
(a) H = 10,000 V_m = 171	$\frac{490}{(1 + 1.9s)}$	0.70	$\frac{0.012}{(1 + 173s)}$	1.3
(b) H = 10,000 V_m = 200	$\frac{490}{(1 + 1.9s)}$	0.82	$\frac{0.0076}{(1 + 85s)}$	1.3
(c) H = 10,000 V_m = 229	$\frac{490}{(1 + 2.0s)}$	0.94	$\frac{0.0044}{(1 + 50s)}$	1.3
(d) H = 25,000 V_m = 167	$\frac{490}{(1 + 2.5s)}$	0.88	$\frac{0.034}{(1 + 280s)}$	1.0
(e) H = 25,000 V_m = 190	$\frac{490}{(1 + 2.4s)}$	1.00	$\frac{0.021}{(1 + 180s)}$	1.0
(f) H = 25,000 V_m = 213	$\frac{490}{(1 + 2.4s)}$	1.10	$\frac{0.0082}{(1 + 72s)}$	1.0

g_{Iu} requires an unusually large time constant. It has been found, however, that the required lag circuit is conveniently available.[1]

Choice of Compromise Values

A comparison of control relations and loop gains for six flight conditions is presented in Table 2. Air-speed loop gain has been corrected for change of air-speed indicator sensitivity with altitude. The conditions represent altitudes of 10,000 and 25,000 ft., and air speeds from 167 to 229 indicated m.p.h.

Fortunately, variation in both time constants and gains is reasonably small. After consideration of Table 2, the following design was recommended for initial flight tests:

$$g_{Ih} = 0.025\ (1 + 2.5s) \text{ deg. per ft.}$$
$$g_{Th} = 12 \text{ lbs. per ft.}$$
$$g_{Iu} = \frac{7.8}{1 + 100s} \text{ deg. per m.p.h. (indicated)}$$
$$g_{Tu} = 380 \text{ lbs. per m.p.h. (indicated)}$$

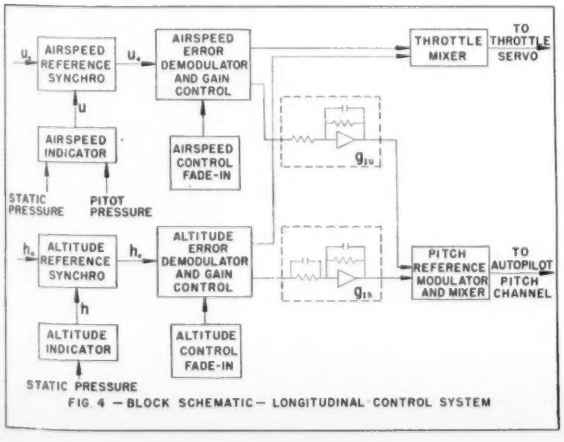

FIG. 4 — BLOCK SCHEMATIC — LONGITUDINAL CONTROL SYSTEM

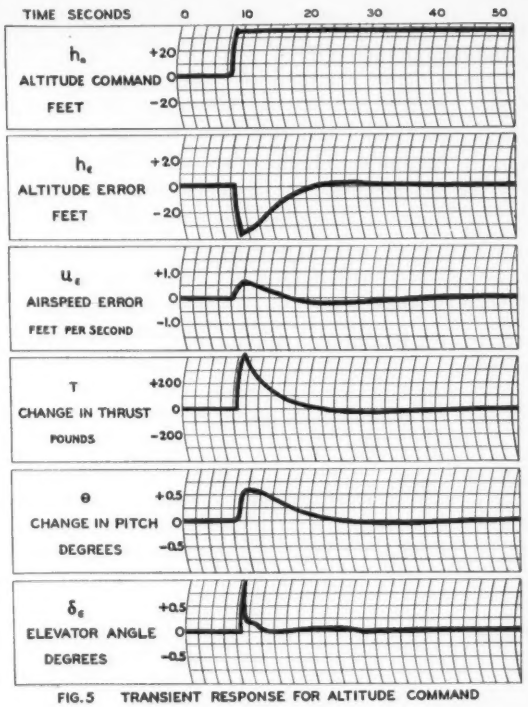
TIME SECONDS 0 10 20 30 40 50
ALTITUDE COMMAND FEET +20 0 -20
ALTITUDE ERROR FEET +20 0 -20
AIRSPEED ERROR FEET PER SECOND +1.0 0 -1.0
CHANGE IN THRUST POUNDS +200 0 -200
CHANGE IN PITCH DEGREES +0.5 0 -0.5
ELEVATOR ANGLE DEGREES +0.5 0 -0.5

FIG. 5 TRANSIENT RESPONSE FOR ALTITUDE COMMAND

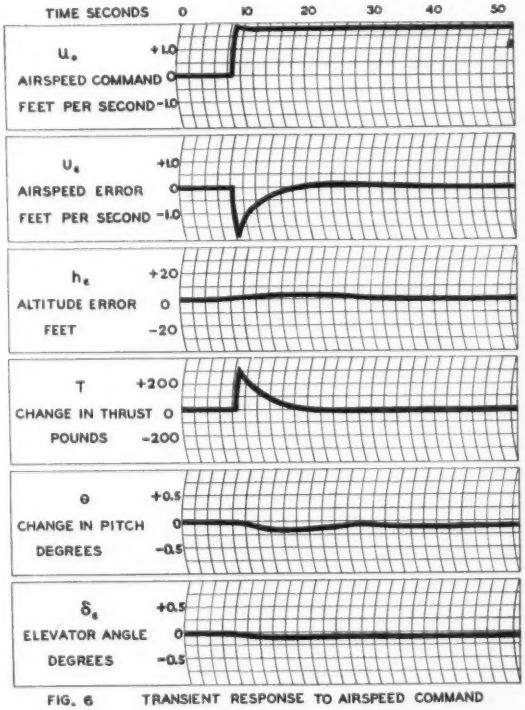
TIME SECONDS 0 10 20 30 40 50
AIRSPEED COMMAND FEET PER SECOND +1.0 -1.0
AIRSPEED ERROR FEET PER SECOND +1.0 -1.0
ALTITUDE ERROR FEET +20 0 -20
CHANGE IN THRUST POUNDS +200 0 -200
CHANGE IN PITCH DEGREES +0.5 0 -0.5
ELEVATOR ANGLE DEGREES +0.5 0 -0.5

FIG. 6 TRANSIENT RESPONSE TO AIRSPEED COMMAND

Mechanization

The integration of the control system elements is shown schematically in Fig. 4. Note that only g_{Ih} and g_{Iu} require frequency-sensitive shaping networks. The operations are performed at d.c.; hence, 400-cycle synchro signals must be demodulated. The throttle servo is operated with d.c. input signals, while the pitch

reference signal is remodulated and enters the autopilot pitch channel at 400 cycles.

Although flight-test data are not yet available, the transient performance of the system has been investigated by means of an electronic analog computer. Typical transient responses are shown in Figs. 5 and 6.

The overall effectiveness of the design is evidenced by the adequate damping and by the small amount of cross-coupling remaining between the air-speed and altitude channels. Although slight cross-coupling does exist, the purpose of the design—to provide stable, accurate control of altitude and air speed—has been accomplished.

Reference

[1] Greenwood, I. A., Holdam, J. V., and Macrae D., *Electronic Instruments*, Radiation Laboratory Series, Vol. 21, 1st Ed., pp. 78–82; McGraw-Hill Book Company, Inc., New York, 1948.

Appendix 1

Determination of Craft Transfer Functions

The craft transfer functions (f_{uI}, f_{uT}, f_{hI}, and f_{hT}) are obtained from the differential equations describing the longitudinal motions of the aircraft and its pitch control system.

Craft Longitudinal Stability Equations

$$\left.\begin{aligned} u(X_u - s) + wX_w + \theta\left(-\frac{g}{57.3}\right) &= -X_T T \\ uZ_u + w(Z_w - s) + \theta\left(\frac{sU_0}{57.3}\right) &= -Z_\delta \delta_e \\ wM_w + \theta(sM_{\dot\theta} - s^2) &= -M_\delta \delta_e \end{aligned}\right\} \quad (6)$$

Altitude Equation

$$sh = (U_0\theta/57.3) - w \quad (7)$$

Pitch Autopilot Equation

$$\delta_e = (A_\theta/\Delta_a)(G_\theta\theta + I)$$

where

$$\Delta_a = (s/\omega_a)^2 + 2\zeta_a\,(s/\omega_a) + 1 \quad (8)$$

Since the design analysis is concerned with the variables u, h, and θ and the control inputs T and I, the original stability equations are rewritten with $[(U_0\theta/57.3) - sh]$ replacing w and $A_\theta(G_\theta\theta + I)/\Delta_a$ replacing δ_e:

$$u(X_u - s) + \left(\frac{U_0\theta}{57.3} - sh\right)X_w + \theta\left(-\frac{g}{57.3}\right) = -X_T T$$

$$uZ_u + \left(\frac{U_0\theta}{57.3} - sh\right)(Z_w - s) + \theta\,\frac{sU_0}{57.3} = -Z_\delta\,(A_\theta/\Delta_a)\,(G_\theta\theta + I)$$

$$\left(\frac{U_0\theta}{57.3} - sh\right)M_w + \theta(sM_{\dot\theta} - s^2) = -M_\delta\,(A_\theta/\Delta_a)\,(G_\theta\theta + I)$$

or, finally,

$$\left.\begin{aligned} u(X_u - s) + sh(-X_w) + \theta\left(\frac{U_0X_w - g}{57.3}\right) &= X_T T \\ uZ_u + sh(s - Z_w) + \theta\left(\frac{U_0Z_w}{57.3} + \frac{Z_\delta A_\theta G_\theta}{\Delta_a}\right) &= -Z_\delta A_\theta\,\frac{I}{\Delta_a} \\ sh(-M_w) + \theta\left(\frac{U_0M_w}{57.3} + \frac{M_\delta A_\theta G_\theta}{\Delta_a} + sM_{\dot\theta} - s^2\right) &= -M_\delta A_\theta\,\frac{I}{\Delta_a} \end{aligned}\right\} \quad (9)$$

Eqs. (9) are the fundamental differential equations describing the system to be controlled. It is possible to effect simplification of these equations in the case of the F-61C system. Since it is desired to control air speed and altitude to the frequency 0.2 rad. per sec., terms of importance only above 2 rad. per sec. can be neglected. Under this approximation the autopilot becomes simply a perfect displacement control ($\Delta_a = G_\theta = 1$). Also, for the F-61C, elevator lift $Z_\delta\delta_e$ is negligible with respect to elevator pitch moment $M_\delta\delta_e$.

The equations used in this investigation to describe the system to be controlled are

$$\left.\begin{aligned} u(X_u - s) + sh(-X_w) + \theta X_\theta &= -X_T T \\ uZ_u + sh(s - Z_w) + \theta Z_\theta &= 0 \\ sh(-M_w) + \theta M_\theta &= -M_\delta A_\theta I \end{aligned}\right\} \quad (10)$$

where

$$X_\theta = (U_0X_w - g)/57.3$$
$$Z_\theta = U_0Z_w/57.3$$
$$M_\theta = \left(\frac{U_0M_w}{57.3} + M_\delta A_\theta + sM_{\dot\theta} - s^2\right)$$

The four system functions (f_{uT}, f_{uI}, f_{hT}, and f_{hI}) are transfer functions between a given output and a given input when the other input is held constant.

For example,

$$f_{uT} = \left.\frac{u}{T}\right|_{I=0} = \frac{\begin{vmatrix} -X_T & -X_w & X_\theta \\ 0 & (s - Z_w) & Z_\theta \\ 0 & -M_w & M_\theta \end{vmatrix}}{\begin{vmatrix} (X_u - s) & -X_w & X_\theta \\ Z_u & (s - Z_w) & Z_\theta \\ 0 & -M_w & M_\theta \end{vmatrix}} = -X_T\,\frac{\Delta_{uI}}{\Delta}$$

The other system functions are found similarly. The four system transfer functions are

$$\left.\begin{aligned} f_{uT} &= -X_T(\Delta_{uz}/\Delta) \\ f_{uI} &= -M_\delta A_\theta(\Delta_{uM}/\Delta) \\ f_{hT} &= -X_T(\Delta_{hz}/s\Delta) \\ f_{hI} &= -M_\delta A_\theta(\Delta_{hM}/s\Delta) \end{aligned}\right\} \quad (11)$$

Appendix 2

Derivation of Control System Open-Loop Transfer Functions in Terms of Stability Derivatives

Altitude Control

Since, if the altitude control system is properly designed, T and I will operate together in such a way as to hold $u \equiv 0$, the required relation between T and I may be obtained from Eqs. (9) by setting $u \equiv 0$. In the resulting set of equations, h, θ, and T are treated as the dependent variables and I as the forcing function:

$$\left.\begin{aligned} sh(-X_w) + \theta X_\theta + TX_T &= 0 \\ sh(s - Z_w) + \theta Z_\theta + 0 &= 0 \\ sh(-M_w) + \theta M_\theta + 0 &= -M_\delta A_\theta I \end{aligned}\right\} \tag{12}$$

Then,

$$T = \frac{\begin{vmatrix} -X_w & X_\theta & 0 \\ (s - Z_w) & Z_\theta & 0 \\ -M_w & M_\theta & -M_\delta A_\theta I \end{vmatrix}}{\begin{vmatrix} -X_w & X_\theta & X_T \\ (s - Z_w) & Z_\theta & 0 \\ -M_w & M_\theta & 0 \end{vmatrix}}$$

or

$$\frac{T}{I} = \frac{M_\delta A_\theta [X_w Z_\theta + X_\theta (s - Z_w)]}{X_T[(s - Z_w)M_\theta + M_w Z_\theta]} = \frac{g_{Th}}{g_{Ih}} \tag{13}$$

Also,

$$\frac{h}{I} = \frac{\begin{vmatrix} 0 & X_\theta & X_T \\ 0 & Z_\theta & 0 \\ -M_\delta A_\theta & M_\theta & 0 \end{vmatrix}}{sX_T[(s - Z_w)M_\theta + M_w Z_\theta]}$$

$$= \frac{M_\delta A_\theta Z_\theta}{s[(s - Z_w)M_\theta + M_w Z_\theta]} \tag{14}$$

Eq. (13) is the required relation between thrust and pitch bias. Eq. (14) is the altitude-to-pitch bias transfer function that results on the assumption that thrust and pitch bias are related as required by Eq. (13). Using the fact that $I = h_\epsilon g_{Ih}$, together with Eq. (14), the altitude control system open-loop transfer function is obtained:

$$\frac{h}{h_\epsilon} = g_{Ih} \frac{M_\delta A_\theta Z_\theta}{s[(s - Z_w)M_\theta + M_w Z_\theta]} \tag{15}$$

Air-Speed Control

To find the required relationship between T and I for the condition that $h_\epsilon \equiv 0$, rewrite Eqs. (9) with h neglected; with u, θ, and I treated as dependent variables; and with forcing function T:

$$\left.\begin{aligned} u(X_u - s) + \theta X_\theta + 0 &= -X_T T \\ uZ_u + \theta Z_\theta + 0 &= 0 \\ 0 + \theta M_\theta + M_\delta A_\theta I &= 0 \end{aligned}\right\} \tag{16}$$

Then,

$$\frac{T}{I} = \frac{-X_T M_\theta Z_u}{M_\delta A_\theta [(X_u - s)Z_\theta - X_\theta Z_u]} = \frac{g_{Iu}}{g_{Tu}} \tag{17}$$

$$\frac{u}{T} = \frac{-X_T Z_\theta}{(X_u - s)Z_\theta - X_\theta Z_u} \tag{18}$$

Since $T = g_{Tu} u_\epsilon$ for $h_\epsilon \equiv 0$,

$$\frac{u}{u_\epsilon} = g_{Tu} \frac{X_T Z_\theta}{X_\theta Z_u - (X_u - s)Z_\theta} \tag{19}$$

Numerical Results

Table 1 is a summary of numerical values of the coefficients appearing in Eqs. (9) for the F-61C for various air speeds and altitudes. At 25,000 ft. and 190 indicated m.p.h. [condition (e)] the altitude control relations resulting from Eqs. (4) and (5) are

$$\frac{g_{Th}}{g_{Ih}} = \frac{500\ (1 + 0.18s)}{(1 + 2.4s)\left[1 + 0.52\left(\frac{s}{3.4}\right) + \left(\frac{s}{3.4}\right)^2\right]}$$

$$\frac{h}{h_\epsilon} = \frac{7.3}{s(1 + 2.4s)\left[1 + 0.52\left(\frac{s}{3.4}\right) + \left(\frac{s}{3.4}\right)^2\right]} g_{Ih}$$

The air-speed control relations are

$$\frac{g_{Iu}}{g_{Tu}} = \frac{0.021\left[1 + 0.50\left(\frac{s}{3.3}\right) + \left(\frac{s}{3.3}\right)^2\right]}{1 + 180s}$$

$$\frac{u}{u_\epsilon} = \frac{0.20}{1 + 180s} g_{Tu}$$

Table 2 presents a comparison of loop gains and control element transfer functions for the six flight conditions of Table 1.

It should be noted that the method used in this appendix to derive the control system transfer functions avoids obtaining explicitly the several craft transfer functions that appear in Eqs. (5). The method used was checked against the more tedious method for flight condition (e) and was found to yield identical transfer functions.

OCEAN TEST TUBE

By
Welman A. Shrader*

CORROSION—THE ARCH ENEMY of metals and men since the beginning of time—is slowly but surely giving ground before the onslaught of modern science. How it behaves, where it comes from, and why it attacks some materials more ferociously than others are but a few of the mysteries now being unraveled through a natural, but man-controlled, "ocean test tube."

The dramatic story that is of interest to every man who builds a ship, an airplane, or a piece of metallic equipment is hourly being written in the sands of Kure Beach and Wrightsville Beach, N.C. Here, in a modern laboratory of the International Nickel Company, Inc., the Navy, Air Force, and a variety of individual companies have joined forces in a common cause against a common enemy—rust.

NATURAL CONDITIONS REMOVE LIMITS ON CORROSION STUDIES

The necessity of providing facilities for the exposure of metals to attack by sea water and marine atmospheres under natural conditions has been demonstrated by the limited practical usefulness of laboratory tests on relatively small specimens in simple salt solutions, synthetic or reconstituted sea water, or in salt-spray boxes. Laboratory tests provide a valuable supplement to tests under natural conditions—particularly in preliminary investigations and in throwing light on the mechanisms of sea-water corrosion and the factors that control it. However, sea water is something more than a mixture of chemicals; it is a living thing, and its corrosive reactions over an extended period can be studied properly only by the exposure of specimens to attack under natural conditions.

Comparative tests at Kure Beach and in synthetic sea water in the laboratory have shown definitely that laboratory conditions are inadequate for measuring the behavior of metals and alloys.

ESTABLISHMENT OF ADEQUATE FACILITIES

The "ocean test tube" had its inception in 1935 when INCO decided to compare the corrosion resistance of low-alloy steels with carbon steel under natural sea-water conditions. With the approval and cooperation of The Dow Chemical Company, specimens were placed in a protected channel through which sea water was

* Director of Publications, Institute of the Aeronautical Sciences.

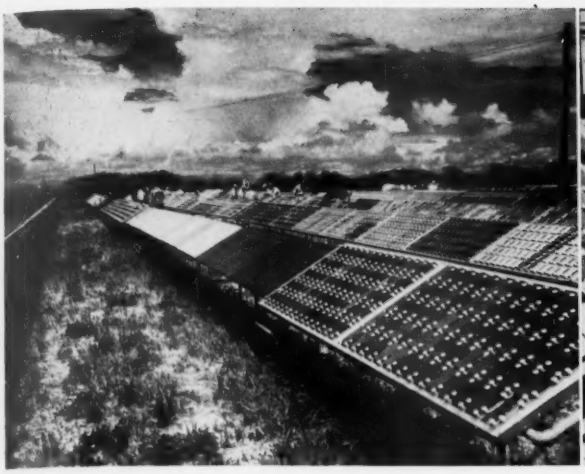

Fig. 1. Atmospheric test racks, 800 ft. from ocean edge, Kure Beach, N.C.

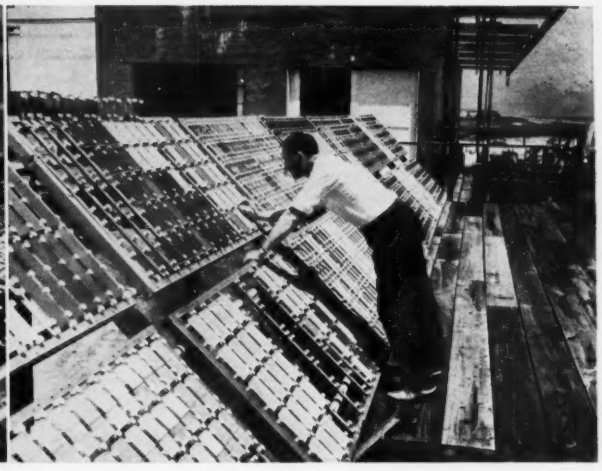

Fig. 2. Sea spray and atmospheric test racks, 80 ft. from water's edge, Kure Beach, N.C.

pumped from the ocean into the bromine plant of the Ethyl-Dow Chemical Company at Kure Beach, N. C.

Soon, other materials were added to the program so that eventually comparative tests were being made on all kinds of ferrous and nonferrous metals and alloys. The testing facilities have since been further extended to observe the effects of marine growth on wood and metals and the results of exposure on such things as protective coatings, rope—and even fishing tackle.

Over 15,000 specimens have been tested in sea water during the past 15 years. Another 20,000 specimens are presently exposed in the atmospheric and salt-water-spray racks, which were erected and added to the project in 1940 (Figs. 1 and 2).

With the completion of INCO's recently dedicated Harbor Island Laboratory at Wrightsville Beach (Fig. 3), American industry and Government now have access to the largest and most modern natural corrosion test center in the world.

Test Projects, Equipment, and Methods

Sea-Water Test Racks and Floats

In sea-water tests, most specimens are exposed on racks continuously immersed at a depth of from 3 to 4 ft. Specimens can also be positioned in such a way that they are automatically exposed alternately to sea water and air for given intervals through the rise and fall of tides.

Facilities have been provided also for hanging specimens from a large pontoon float when it is necessary to maintain a constant water line or a constant depth of immersion in spite of the tide.

The period of exposure of a group of specimens may vary from 6 months (rarely less) to several years; the longest to date is 12 years.

Fig. 4 shows the structure of the test rack and the manner of putting the rack into place.

Atmospheric and Spray Tests

Since corrosion by marine atmospheres is equal in importance to corrosion by salt water, facilities have been provided for extensive atmospheric tests. Two sites, one directly on the beach approximately 80 ft. from the water's edge and the other about 800 ft. back from the shore, have been established (Figs. 1 and 2). Here, racks that can accommodate thousands of specimens are constantly utilized and checked by International Nickel and cooperating agencies and companies. The racks on both sites are set at a 30° angle, thus providing a uniform comparison between all specimens.

It is interesting to note how the corrosive effect on materials varies between the locations. Although the difference in distance from the surf is only 700 ft., the corrosive effect on certain metals at the beachside lot is ten times faster than at the main lot.

Space is also provided at the main lot for the placement and testing of certain complete aircraft components. Currently being tested are some wing sections, ailerons, flaps, fuselage sections, wheels, brakes, etc.

Fig. 3. Harbor Island Laboratory.

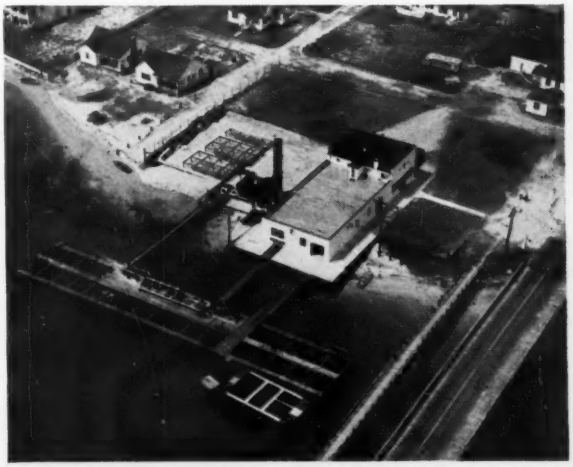

Fig. 4. Setting up a test rack of specimens at Harbor Island.

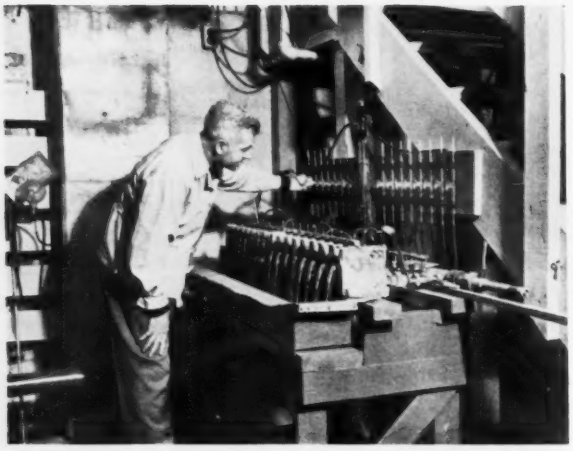

Fig. 5. Aspirator type of jet testing apparatus at Harbor Island.

Fig. 6. Growing "hair" on a billiard ball.

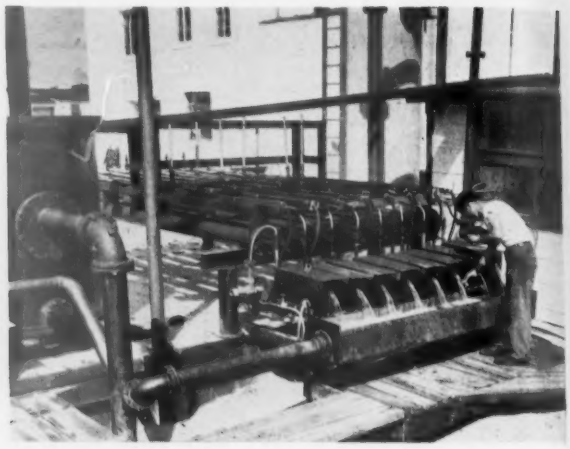

Fig. 7. Wallace & Tiernan chlorination test apparatus set up at Harbor Island.

Velocity Effects

The need for more precise information on the abilities of alloys to withstand the severe erosive effects associated with such uses as condenser tubes, piping systems, pump impellers, propellers, and other underwater parts of fast moving ships has led to the design and operation of several types of erosion-testing apparatus. Set up in the Harbor Island Laboratory, these different whirling-arm, rotating spindle, or pressure-jet types of apparatus are capable of simulating practically any kind of condition encountered in actual sea-water operations.

Fig. 5 shows the aspirator type of jet testing apparatus developed at Kure Beach. This device subjects test specimens to the erosive effects of high-velocity jets of sea water mixed with air bubbles. It has been particularly useful in developing and evaluating condenser tube alloys resistant to "impingement attack."

The potential relationships and polarization characteristics of metal and alloys in sea water flowing at different controlled velocities are also being studied through equipment designed at the laboratory. Investigations with this apparatus are yielding valuable fundamental data concerning the behavior of galvanic couples.

Marine Fouling

The study of antifouling characteristics of metals, alloys, plastics, and protective coatings has been an important phase of research during the past few years. How industry literally can be put "behind the 8 ball" by marine fouling is shown in Fig. 6, where a reasonable facsimile of hair has been made to grow on a billiard ball.

Exhaustive tests on the use of chlorine to control fouling of intake tunnels and sliming of condenser surfaces are being made through the use of equipment shown in Fig. 7. The object is to work out conditions of treatment with respect to water velocities, concentra-

Fig. 8. Some of the company plaques hanging in the Conference Room at Harbor Island—mute evidence of the cooperative spirit in this joint enterprise.

tions of chlorine, and cycles of additions which will assume the desired results most economically and without aggravating corrosion.

Industry-Wide Cooperation

These corrosion testing facilities, affectionately dubbed the "Sea Horse Institute," are a shining example of American industry at work for the mutual benefit of all. While they are built, owned, and operated by the International Nickel Company, Inc., more than 100 other companies and the U.S. military services have free access to them and are currently conducting tests.

It is not unusual to find specimens of directly competing products along side each other in the test racks, with engineers from all companies working hand-in-hand toward a common goal—the control of corrosion.

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An Experimental Investigation of Supersonic Lattice Flow*

JAMES E. O'NEILL†
Packard Motor Car Company

Introduction

In recent years a growing interest has been centered on the possibility of achieving high compression ratios across an axial-flow compressor of comparatively few stages by operating at supersonic relative inlet velocities. Since the development work being conducted by the Aircraft Engine Division of the Packard Motor Car Company hinged on the successful design of such a component and since specific design data were lacking, it was necessary to supply the required information by conducting experimental flow studies as a part of the development program.

The most promising approach to the problem appeared to be a correlated program of model wheel experiments and two-dimensional flow studies in a lattice tunnel such as had been used as a tool in the design of subsonic compressors. Contributing to the attractiveness of this approach was the possibility of utilizing the schlieren apparatus to supplement information provided by pressure measurements in the lattice tests.

This paper discusses the supersonic lattice tests performed during 1948 as a part of the correlated program at the Packard Motor Car Company. The test subject is the initial design of a compressor wheel to operate at a supersonic relative inlet velocity with a transition to a subsonic relative exit velocity. Prior to these lattice studies, tests on a model wheel of this design verified that transition to a subsonic relative velocity occurred within the blading at a static pressure ratio across the wheel of 1.40. The purpose of the lattice tests was that of analyzing the mechanism through which the pressure rise occurred across the wheel and of determining the source of losses. When properly correlated with further model wheel tests, it was expected that the results of these two-dimensional tests could be applied to modify the various lattice parameters so as to obtain the highest possible pressure rise at a minimum of loss.

This program was stopped before completion by the termination of a Government contract of which it was a part. However, despite their preliminary nature, there were obtained some lattice test results of possible interest to others working with supersonic compressors.

* Grateful acknowledgment is made of the suggestions offered during the course of these tests by Drs. A. A. Fejer, G. F. Wislicenus, and H. S. Tsien. The author wishes to express his appreciation also to J. C. Westkaemper and R. L. Jennings, of Sverdrup & Parcel, Inc., for their assistance with the drawings.

† Development Engineer. Now with Sverdrup & Parcel, Inc.

Test Apparatus

Air Supply System

The supersonic lattice tunnel of the Packard Motor Car Company was designed during 1947 under the supervision of Dr. G. F. Wislicenus. A controlling factor in the project was the necessity of designing in order to utilize the various blowers, pumps, etc., available at the Toledo, Ohio, plant.

The tunnel is of the push-pull type, having a centrifugal blower on the upstream end and a battery of vacuum pumps on the downstream end. Upon leaving the blower, the air is dried by passing it through a refrigerating unit maintaining a temperature of −70°F., which is sufficiently low to result in an absolute humidity of 0.00002 lb. of water per lb. of dry air. The air is then heated by electrical heaters to a stagnation temperature of 80° to 120°F. at the nozzle inlet.

A stagnation pressure at the nozzle inlet up to 50-in. Hg (Abs.) is produced by the blower, and the vacuum pumps provide for a test-section static pressure down to 5.50-in. Hg (Abs.).

Flexible Nozzle

A unique feature of the tunnel is the method of providing for flexibility of the nozzle, shown in Fig. 1. Adjustable jacks sliding vertically determine the nozzle contour. The flexible nozzle walls are made of thin sheet steel and are held against the jacks by a pressure difference across the sheet, established by evacuating the region housing the jacks to a pressure of 5.0-in. Hg (Abs.). In the nozzle flow, the lowest pressure encountered is 5.5-in. Hg at the nozzle exit.

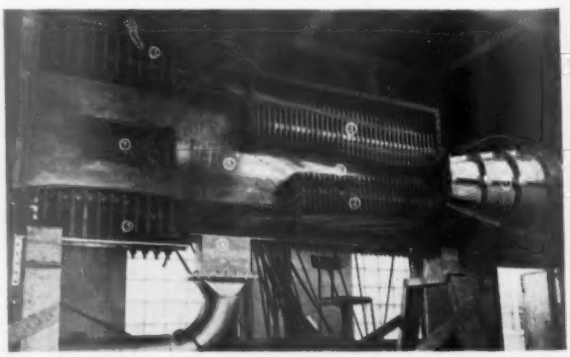

Fig. 1. Side view of tunnel showing positioning jacks (2), and lead to vacuum pump maintaining low pressure in the jack region (4).

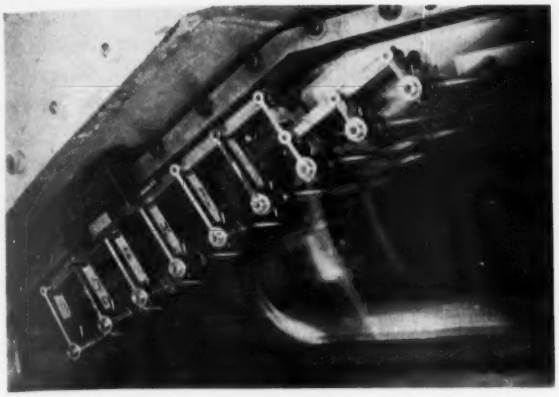

FIG. 2. Device for holding and turning vanes.

The evacuated regions behind the two nozzle walls are connected by a duct passing diagonally between them outside the air stream. Presence of this duct explains the odd shape of the test-section windows. Furthermore, these two regions are joined to two corresponding regions behind the diffuser walls. Thus, only one lead is necessary from the evacuated regions to the special vacuum pump maintaining their low pressure.

An approximate setting of the jacks for a given Mach Number is made by inserting a shaped wooden template from the side, and final minor corrections are made as required during calibration runs.

Test Section

At the nozzle exit the flow enters a large chamber as a partially free jet bounded by the two glass sidewalls only. Dimensions of the nozzle at its exit are 6.75 by 5.5 in. (wide). In this flow the blades span the entire width, and trunnions on each end project through holes drilled in glass windows. The trunnions are held by the exterior linkage illustrated in Fig. 2, which turns all the blades simultaneously to vary the angle of attack.

Diffuser

The tunnel is equipped with a flexible diffuser similar in construction to the nozzle which can be adjusted to receive the inclined flow leaving the lattice. It was not necessary to use the diffuser in the experiments discussed, so it was left in the retracted position as shown in Fig. 1.

Instrumentation

Pressure-measuring instrumentation consisted mainly of several static pressure wall taps distributed throughout the flow field upstream and downstream of the lattice. Some of these were located in the flexible walls of the nozzle. Included among the wall taps was one located on the sidewall of the large chamber to which the cascade flow was evacuated, in the still air region about 10 in. below the jet. This recorded a static pressure approximately equal to that in the jet.

A static pressure probe was used to verify conclusions drawn from study of schlieren photographs. It was made of 0.042-in. outside diameter hypodermic tubing, having static holes drilled with a No. 76 drill about $1/4$ in. from the tip. It was assumed that the probe diameter was sufficiently small to result in negligible pressure rise across the shock envelope attached to the tip.

The schlieren system is conventional and is equipped with both a continuous light source with which photographs can be taken at 1/150 sec. and a spark discharge of approximately 1-microsec. duration for instantaneous photographs.

PROCEDURE

Schlieren observations and static pressure measurements were made at constant attack angle, while static pressure ratio across the lattice was varied from 0.5 (expansion) to 2.0 (compression).

Since traversing probes were not yet installed downstream of the test section, no information is available on the wake thickness or exit flow direction. An approximation of the exit flow direction was obtained by measuring wake direction in the schlieren photographs.

The tests discussed here were those on a lattice having properties as indicated in Fig. 3. The range of attack angles covered was from 0° to 10°.

RESULTS

General

An unexpected result was the failure of the flow to reach subsonic velocities in the blading, as was experienced in all the previous wheel tests. This is probably to be attributed to the discrepancy in Mach Number of the relative inlet flows, the highest value reached in the time available in wheel tests being $M = 1.50$ and the lowest value in the lattice tests being $M = 1.97$. If the compression process were isentropic, the Mach Number of the relative lattice flow would have to be reduced from 1.50 to 1.26 in order to result in the static pressure ratio of 1.40. Considering that the compression does not occur isentropically and that, consequently, a reduction of stagnation pressure occurs across the lattice, it is not difficult to conceive of a subsonic Mach Number at the lattice exit being necessary to attain the pressure ratio of 1.40. Another factor involved in this discrepancy is the effect of three-dimensional flow.

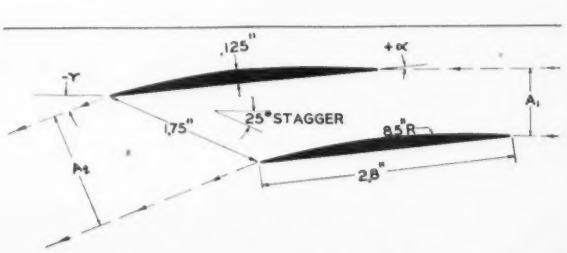

FIG. 3. Configuration of test lattice.

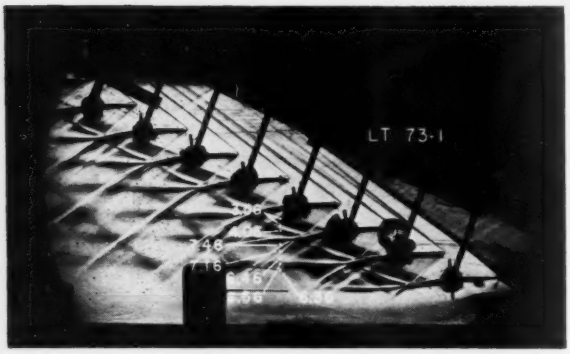

FIG. 4. Schlieren photograph of a typical compression process; inlet Mach Number = 1.97, stagger angle 25°, static pressure ratio 1.35, attack angle = 6°.

Analysis of the Typical Compression Process

Fig. 4 is a schlieren photograph of the flow through the blades at an inlet Mach Number of 1.97, at a stagger angle of 25°, and with a pressure ratio of 1.35 existing across the lattice. Fig. 5 is a schematic sketch of the same flow field.

An immediately obvious difficulty is presented by the fact that each vane of the test lattice of finite length receives a flow that has accumulated alterations in Mach Number, flow direction, and entropy in passing through the upper bow waves off preceding vanes. As a result, the inlet flow pattern of the test lattice of finite length can be nonuniform along its length if these bow waves are of significant strength. On the wheel, each vane channel must receive a relative flow having the same inlet conditions, the properties of which depend on how many preceding bow waves of finite strength must be crossed by the flow. Flows across finite lattices will be distorted by the fact that the first vane receives a flow devoid of any such accumulative effects unless the existence of accumulated alterations is eliminated, as when the flow under consideration is such that the upper waves are intercepted by the next vane. These accumulations are partially eliminated when the bow wave effects on direction and Mach Number are counteracted by an expansion before the next vane is encountered. Fortunately, this happened to be the case in the tests under discussion. Of course, the accumulated entropy change is not so easily corrected for; however, across bow waves producing flow deviation of 10° or less the entropy change is small.

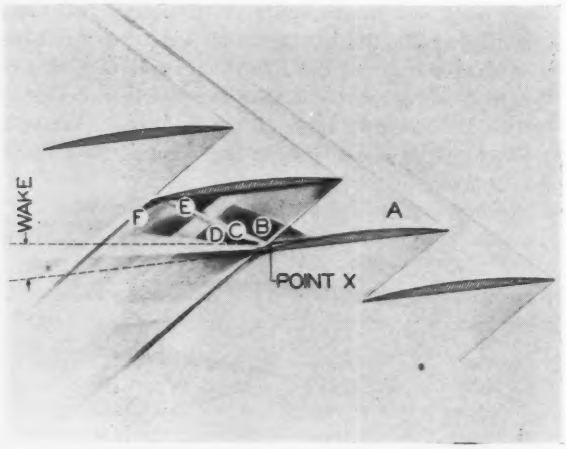

FIG. 5. Schematic sketch of Fig. 4.

A similar consideration is to be applied to the extended wave pattern off the lower trailing edges of the vanes. Both of these extended wave patterns add to further distortion of the flow picture when they are reflected from the tunnel boundaries, the bow-wave pattern reflecting from the upper nozzle wall and the trailing edge waves reflecting from the lower boundary of the jet leaving the lattice.

Another detrimental effect of the finite length of the lattice is due to the incongruous passages between each end blade and the nozzle wall. This has not been investigated as yet. Furthermore, it is to be noted that tunnel-wall boundary layers have not been removed. Their presence will undoubtedly have an effect on the lattice flow.

The angle of inclination of the bow waves in Fig. 4 is fairly constant at 40° except for the first one at 35°. Downstream of this blade the flow field is uniform but has a Mach Number 10 per cent less than the free stream. Flow direction has not been affected by passage through this first wave. Fanning out of the upper bow waves is attributed to slight spanwise variations in the flow or to spanwise bending of the vanes under air load.

Referring to the sketch, Fig. 5, compression occurring in the preceding bow waves is counteracted in the respective expansion zones corresponding to the region *A*. Thus, the flow conditions are approximately similar at the leading edge of each vane. Upstream of the point *X*, where the lower bow wave off the fourth vane contacts the surface, there is a dark band *B* wherein compression occurs as the boundary-layer thickens. The compression zone *B* ends where an expansion fan *C* appears as a reflection of the lower bow wave from the separated boundary layer at the point *X*. Downstream of this expansion fan is a compression zone *D* having the function of adjusting the flow direction and pressure to meet the flow leaving the lower surface of the blade number three. The alternate black and white zones in region *E* are reflections from the upper vane of the waves originating on the lower vane described above. Finally, the group of waves marked *F* completes the compression process in the lattice flow.

An approximate verification of this qualitative analysis was established by measuring static pressures along a vertical traverse downstream of the passage. Measured values are marked on the schlieren photograph, Fig. 4. These indicate that, at least in this case, the major portion of the compression obtained in a flow through the lattice is contributed by the narrow compression zone *D*, which exists because of the interaction at point *X*.

Effect of Back-Pressure Variations

A series of runs was made at 0° angle of attack and will be discussed briefly because it provides an example of what occurs when the limitations of the apparatus are exceeded. The configuration was such that the bow waves off the first two blades were reflected from the top wall too far upstream, with the result that flow impinging on the fourth vane was strongly influenced by the reflection. Beyond that vane the flow was badly distorted. Fig. 6 is a schlieren photograph of this run.

The run at an angle of attack of +4° over a range of pressure ratios across the lattice is typical of those at higher angles. Schlieren photographs taken at the extreme values of the pressure ratio appear as Figs. 7 and 8 and will be used to illustrate the effect of back-pressure variation.

The most apparent effect of variation in back pressure is the change in direction of flow leaving the lattice. At a pressure ratio of 0.47 it leaves in a downward direction or with a component in the direction of wheel rotation, and at a pressure ratio of 2.00 the flow is turned upward by the lattice—i.e., away from the direction of rotation.

Another noticeable variation in the general flow picture is a widening of the compression zone marked *B* on the sketch, Fig. 5. This is a compression resulting from the thickened boundary layer in the neighborhood of the lower bow-wave reflection. There is no change in the chordwise location of the interaction point, but the boundary of zone *B* spreads upstream, indicating an increase in the range of influence of the shock-wave and boundary-layer interaction and probably a more rapid thickening of the boundary layer.

At the higher pressure ratios, a region similar to *B* appears on the lower blade surfaces and spreads upstream with further increases in pressure ratio. This region probably existed at the lower pressure ratios but was blotted out by the vane trunnion holes in the glass.

Further changes occurring with increasing back pressure are an increase of inclination of the expansion fan *C* and a widening at the base of the compression region *D*.

Further insight into the flow process is acquired by considering the effect of back-pressure changes on the lattice turning angle. Fig. 9 is a plot of these data. The pressure p_2 is that measured about 10 in. below the exit jet in the chamber into which the lattice flow is evacuated and is approximately equal to the static pressure across the jet as it leaves the lattice. Pressure p_1 is static pressure of the lattice inlet. Also indicated along the abscissa are area ratios corresponding to the turning angles.

In the region where A_2 is greater than A_1, the pressure ratio is less than unity—i.e., an expansion occurs through the lattice. The pressure ratio is, in general, approximately equal to that across a widening channel of ratio A_2/A_1 in which expansion is occurring isentropically. Considering the existence of shock waves within the

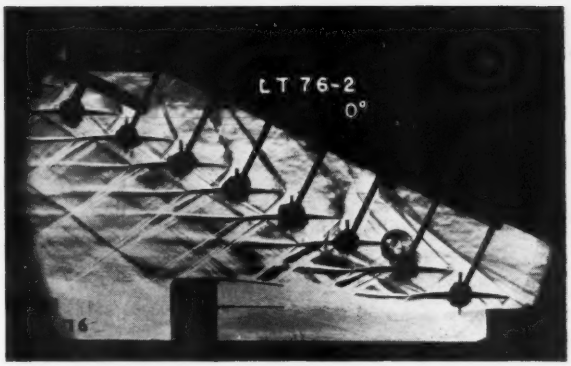

FIG. 6. Flow that could not be completely established.

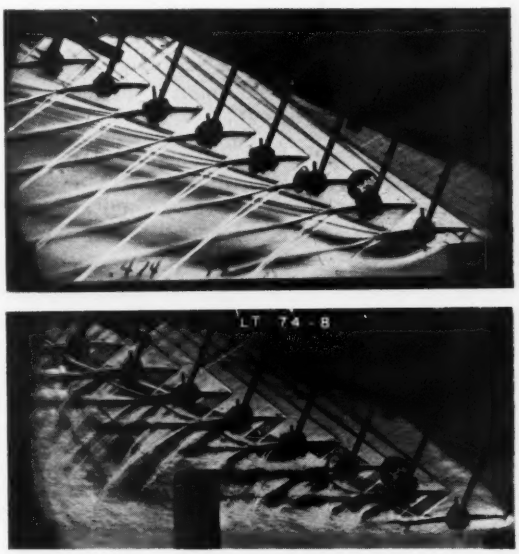

FIG. 7 (*top*). Flow at inlet Mach Number of 1.97 with static pressure ratio of 0.47 and attack angle of +4°.
FIG. 8 (*bottom*). Flow at inlet Mach Number of 1.97 with static pressure ratio of 2.00 and attack angle of +4°.

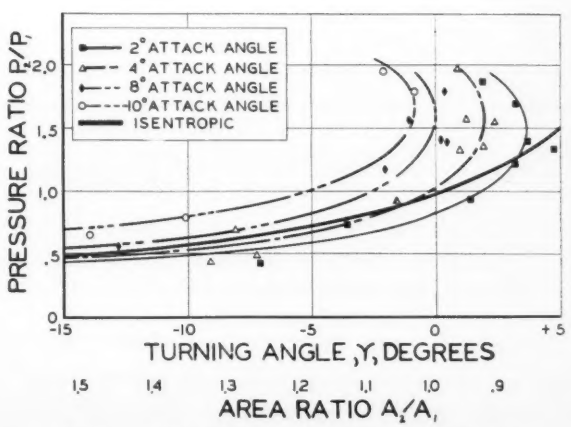

FIG. 9. Static pressure ratio versus turning angle.

lattice channels, it is to be expected that the exit static pressure ratio would exceed the isentropic value. Apparently the net effect of the shock waves is small enough to be negligible or else it is counteracted by viscous losses.

As the area ratio approaches unity, the pressure ratio increases as would be expected, but the rate of increase exceeds the rate along the isentropic curve, indicating a growing strength of the shock-wave pattern. Eventually, the curve becomes vertical, and the pressure ratio rise is continued by the increasing strength of the shock-wave pattern only. Finally, the curve turns back toward the region of higher values of A_2/A_1 as p_2/p_1 continues to rise. This is contrary to the behavior in the isentropic case, where an increasing A_2/A_1 corresponds to a decreasing p_2/p_1, and is indicative of further growth in the strength of the shock-wave patterns.

It is concluded that three factors are involved in the static pressure change as air passes through the lattice. These are the geometry of the channel, the shock-wave pattern, and viscous losses that reduce the pressure. At low values of pressure ratio, the shock-wave pattern is weak or else compensated for by the viscous losses, with the result that the pressure ratio is approximately that deduced from consideration of blade channel geometry changes above. At pressure ratios around 1.0, the geometrical factor A_2/A_1 begins to remain constant, while the shock-wave pattern assumes a stronger role. Finally, at the point where the curves begin to turn back, the shock-wave effect becomes increasingly strong and the pressure ratio continues to rise despite an adverse geometrical effect (decreasing A_1/A_2), as well as strong viscous losses apparent in the schlieren photos.

At low values of pressure ratio, the turning angles at constant pressure ratio cover a wide range of values, indicating considerable variation in strength of the shock-wave patterns. This spread decreases until, at a p_2/p_1 value of 1.50, there is a minimum spread, indicating shock patterns of approximately equal strength.

Tests with Inverted Vanes

The vane configuration tested at a Mach Number of the relative inlet flow of 1.97 was designed on the basis of model wheel tests made at lower Mach Number which indicated a transition to subsonic Mach Number within the blading. Accordingly, the vane passage was designed as a diverging one. For supersonic lattice flow without transition to subsonic flow, this configuration is not so suitable as one having a converging vane passage.

After it became apparent that no transition occurred, an attempt to adapt the design for completely supersonic flow was made by inverting the blades, thus providing a converging exit channel. These attempts were unsuccessful because of serious nonuniformities in the bow-wave pattern resulting from failure to provide conditions such that each vane received a flow at the same Mach Number and direction.

Conclusions

(1) The interaction of shock waves and boundary layers, which is a difficult factor to evaluate analytically, is a significant factor in the compression process of the tested configuration.

(2) When relative inlet and exit flows are both supersonic, at a given attack angle the flow turning angle decreases with increasing pressure ratio until a minimum value is reached at a pressure ratio of about 1.5. The minimum angle varies with attack angle. This variation in turning angle has been interpreted as an indication that the two main factors effecting a static pressure rise through the cascade are undergoing a change in their relative importance as the pressure ratio increases, the shock-wave effect becoming stronger and the area ratio effect diminishing.

(3) For a lattice having supersonic inlet and exit flows, a blade shape with upswept tail, which will result in an area reduction within the channel ($A_2 < A_1$), would bear investigation, but the inlet portion of the channel would have to be similar to that of the present configuration so as to keep a practical bow-wave configuration.

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A Method of Presenting the Performance of Turbojet Engines

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Westinghouse Electric Corporation

ABSTRACT

A report is given of a continuous effort over the past 9 years to develop a suitable method of presenting the performance of turbojet engines. The shortcomings of at least six methods we have previously used are discussed. For instance, one of the earlier methods required a relatively small number of performance curves to be drawn by the engine supplier. However, it was almost impossible, using this method, for the airplane designer to correct the turbojet performance for the effect of compressor air bleeding or the effect of additional power extraction from the gearbox. A correction factor method described in detail herein indicates clearly to both the engine and aircraft designer the loss in turbojet performance to be expected because of additional inlet or exhaust ducting losses, compressor air bleeding, power extraction, or nonstandard atmospheric conditions.

THE CURRENT METHOD

THE SKETCHES SHOWN on Figs. 1 to 12 represent the types of performance curves employed in the method. The typical performance curve, Fig. 1, is drawn for several altitudes and represents the ideal engine performance for standard N.A.C.A. Altitude Conditions, without duct loss, without air bleeding, and without power extraction from the gearbox.

The engine performance for the case with inlet or exhaust duct losses, bleeding air from the compressor outlet, extracting power from the gearbox, or nonstandard atmospheric temperature can be obtained by means of the correction equations in Fig. 13, using the correction factors (C_d, $C_{bl.}$, C_{P_T}, C_T, etc.) shown on the performance curves.

The basis of the method and the development of the correction equations and the correction factors is shown on Figs. 15, 16, and 17. The method, as can be seen from a study of the development, consists of relating the derivatives of the equations used in the cycle calculations to obtain the effect on thrust and fuel flow, for instance, due to a change in compressor inlet pressure caused by air inlet duct loss.

In simpler words, the effect of a 1 per cent change in compressor inlet pressure is carried through the engine to obtain its effect on the airflow; the compressor outlet pressure and temperature; the gross thrust; and, eventually, the net thrust. The development presented on Figs. 15, 16, and 17 is carried out assuming that the effects of duct losses, air bleeding, power extraction, and nonstandard ambient temperature occur simultaneously.

The results of the analysis are summarized by eight equations, the coefficients of which are tabulated on Fig. 18. This figure shows the total change in the different quantities listed in the left-hand column as the sum of the changes due to the quantities heading the columns. Multiplying the coefficients on Fig. 18 by the applicable changes heading the columns and adding will give the change in the quantities listed in the left-hand column. An examination of Fig. 18 will show that the change in thrust due to the introduction of a duct loss or an air bleed depends on what happens to the turbine inlet temperature ($\Delta T_{t4}/T_{t4}$) when the losses are introduced (refer to the last column of Fig. 18). Thus, the thrust loss factors must depend on the type of engine control. As an example, for the case of an engine with constant exhaust nozzle area ($\Delta A/A = 0$), the change in turbine inlet temperature ($\Delta T_{t4}/T_{t4}$) must be eliminated before the two equations [Eqs. (29) and (23)] obtained from the first and seventh lines of Fig. 18.

The summary equations given on Fig. 19 were obtained from Fig. 18 in the above manner after assuming three typical types of engine controls: constant turbine inlet temperature, constant turbine outlet temperature, or fixed exhaust nozzle area. The quantities tabulated on Fig. 19 are therefore the expressions for the correction factors for engines having the three types of controls indicated. Other expressions for different types of controls can similarly be derived from the equations of Fig. 18.

The correction factors may readily be calculated by the engine builder by means of the expressions of Fig. 19, using the engine performance data already required to plot the performance curves of the type shown on Fig. 1.

HISTORY OF THE DEVELOPMENT OF THE METHOD

Early in 1941, the performance of turbojet engines was first plotted in this country in terms of dimensionless quantities such as

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† Research Engineer, Aviation Gas Turbine Division.

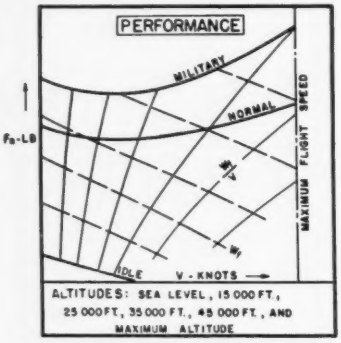


Fig. 1

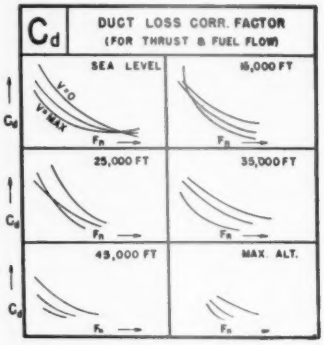


Fig. 2

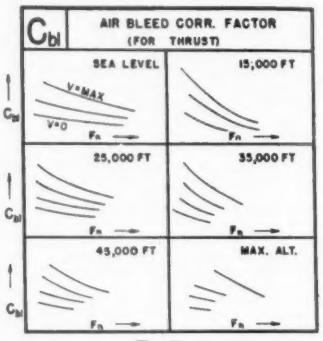


Fig. 3

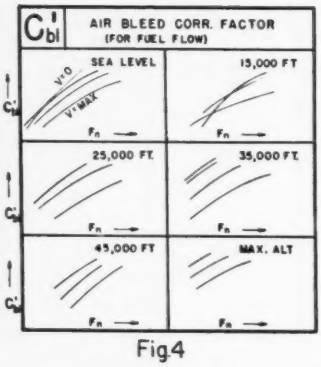


Fig. 4

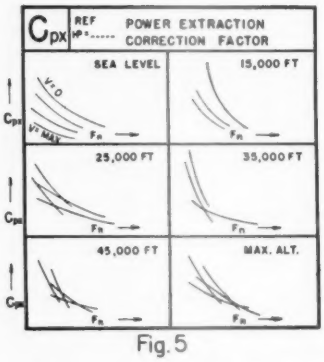


Fig. 5

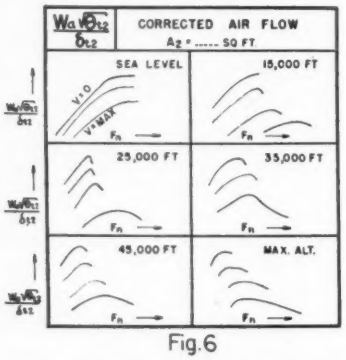


Fig. 6

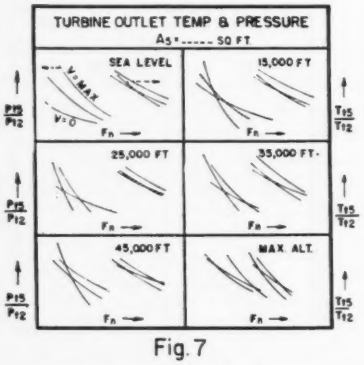


Fig. 7

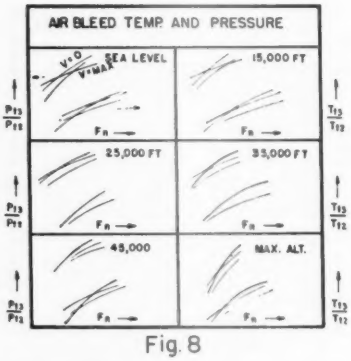


Fig. 8

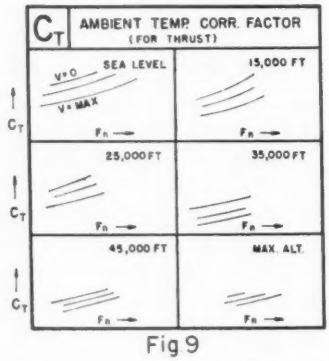


Fig 9

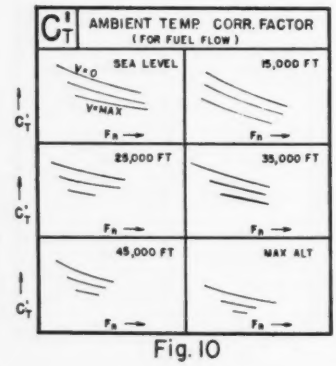


Fig. 10

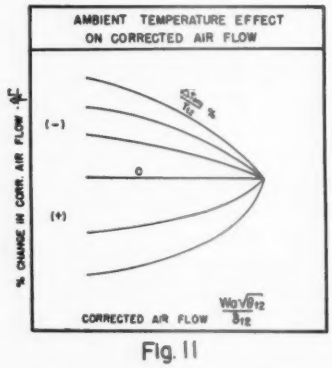


Fig. 11

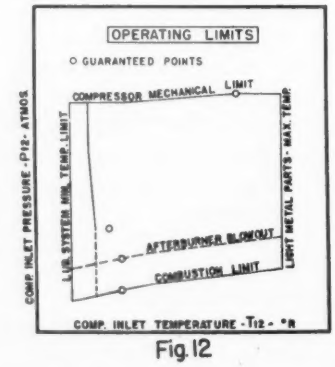


Fig. 12

TYPICAL SET OF PERFORMANCE CURVES

CORRECTION EQUATIONS

THE PERCENT REDUCTION IN NET THRUST $\left(\frac{\Delta F_n}{F_n}\right)$ OR FUEL FLOW $\left(\frac{\Delta w_f}{w_f}\right)$ DUE TO INLET DUCT LOSSES, EXHAUST DUCT LOSSES, BLEEDING AIR FROM COMPRESSOR OUTLET, EXTRACTING POWER FROM THE GEARBOX, AND AMBIENT TEMPERATURE VARIATION TAKEN INDIVIDUALLY OR IN COMBINATION CAN BE OBTAINED FOR ANY ALTITUDE AND FLIGHT SPEED BY MEANS OF THE FOLLOWING EQUATIONS

(1) $$\frac{\Delta F_n}{F_n} = \underbrace{(1+C_d)\left(\frac{\Delta P_{12}}{P_{12}}\right)_d}_{\text{INLET DUCT LOSS}} + \underbrace{C_d\left(\frac{\Delta P_{15}}{P_{15}}\right)_d}_{\text{EXHAUST DUCT LOSS}} + \underbrace{C_{bl}\left(\frac{w_{bl}}{w_a}\right)}_{\text{AIR BLEED}} + \underbrace{C_{Px}\left(\frac{HP_{EXT}}{HP_{REF}}\right)}_{\text{POWER EXT.}} + \underbrace{C_{T1}\left(\frac{\Delta T_{am}}{T_{am}}\right) + C_{T2}\left(\frac{\Delta w_a}{w_a}\right)_T}_{\text{AMBIENT TEMPERATURE VARIATION}}$$

(2) $$\frac{\Delta w_f}{w_f} = \underbrace{\left(\frac{\Delta P_{12}}{P_{12}}\right)_d}_{\text{INLET DUCT LOSS}} + \underbrace{C'_d\left(\frac{\Delta P_{15}}{P_{15}}\right)_d}_{\text{EXHAUST LOSS}} + \underbrace{\left[1+C'_{bl}\left(1+\frac{w_{bl}}{w_a}\right)\right]\left(\frac{w_{bl}}{w_a}\right)}_{\text{AIR BLEED}} + \underbrace{C'_{Px}\left(\frac{HP_{EXT}}{HP_{REF}}\right)}_{\text{POWER EXT.}} + \underbrace{C'_{T1}\left(1+\frac{\Delta w_a}{w_a}\right)\left(\frac{\Delta T_{am}}{T_{am}}\right) + \left[-1+C'_{T2}\left(1+\frac{\Delta w_a}{w_a}\right)\right]\left(\frac{\Delta w_a}{w_a}\right)_T}_{\text{AMBIENT TEMPERATURE VARIATION}}$$

(3) $$\underbrace{\left(\frac{\Delta w_a}{w_a}\right)}_{\text{AMBIENT TEMPERATURE VARIATION}} = \frac{\Delta\Gamma}{\Gamma} - \bar{M}\left(\frac{\Delta T_{am}}{T_{am}}\right) \quad \text{WHERE} \quad \bar{M} = \frac{M_o^2\frac{k}{2}+\frac{1}{2}}{M_o^2\frac{k-1}{2}+1}$$

M_o = FREE STREAM MACH NO
k = RATIO OF SPECIFIC HEATS $\left(\frac{c_p}{c_v}\right)$

WHERE

$\frac{\Delta P_{12}}{P_{12}}$	PERCENT LOSS IN COMPRESSOR INLET TOTAL PRESSURE DUE TO INLET DUCT LOSS
$\frac{\Delta P_{15}}{P_{15}}$	PERCENT LOSS IN TOTAL PRESSURE BETWEEN TURBINE OUTLET AND EXHAUST NOZZLE INLET
$\frac{w_{bl}}{w_a}$	PERCENT OF TOTAL ENGINE AIR FLOW BLED FROM COMPRESSOR OUTLET
$\frac{HP_{EXT}}{HP_{REF}}$	PERCENT OF REFERENCE HORSEPOWER EXTRACTED FROM THE GEARBOX FOR AIRCRAFT ACCESSORIES
HP_{REF}	REFERENCE HORSEPOWER ARBITRARILY TAKEN AS TEN PERCENT OF THE SEA LEVEL STATIC MILITARY JET HORSEPOWER (GIVEN ON PERFORMANCE CURVES)
$\frac{\Delta T_{am}}{T_{am}}$	PERCENT INCREASE IN AMBIENT TEMPERATURE OVER THE STANDARD NACA AMBIENT TEMPERATURE FOR THE ALTITUDE CONCERNED
$\left(\frac{\Delta w_a}{w_a}\right)_T$	PERCENT INCREASE IN ACTUAL ENGINE AIR FLOW DUE TO AMBIENT TEMPERATURE VARIATION
$\frac{\Delta\Gamma}{\Gamma}$	PERCENT INCREASE IN CORRECTED ENGINE AIR FLOW DUE TO AMBIENT TEMPERATURE VARIATION
$C_d, C_{bl}, C_{Px}, C_{T1}, C_{T2}$	THRUST CORRECTION FACTORS FOR DUCT LOSS, AIR BLEED, POWER EXTRACTION, AND AMBIENT TEMPERATURE VARIATION
$C'_d, C'_{bl}, C'_{Px}, C'_{T1}, C'_{T2}$	FUEL FLOW CORRECTION FACTORS FOR DUCT LOSS, AIR BLEED, POWER EXTRACTION, AND AMBIENT TEMPERATURE VARIATION

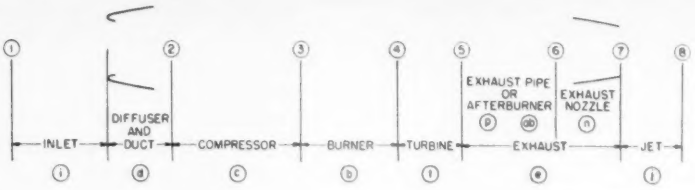
FIG. 13 CORRECTION EQUATIONS

F/pA = dimensionless thrust
$w_a a/pAg$ = dimensionless airflow

These quantities enabled one to draw dimensionless curves that (if Reynolds Number effects were neglected) were applicable to all altitudes and flight speeds. One disadvantage found in using these quantities was the odd numerical magnitude of the quantities. As an example, the value of the dimensionless thrust for a typical engine would be 0.70. The magnitude of this number, together with the fact that it was dimensionless, led to the idea of using corrected quantities in place of dimensionless quantities. The expression for corrected thrust was obtained from the dimensionless thrust by deleting the area A (only one engine is considered at a time) and by dividing the pressure by the standard sea-level pressure. The corrected quantities have the advantage that they have dimensions and are equal in magnitude to the value under standard sea-level conditions. A list of expressions for corrected quantities is given on Fig. 14.

Shortly after the invention of corrected quantities, another difficulty became apparent. It was difficult for the airplane designer to make allowances for inlet ducting losses. This difficulty was quickly overcome

SYMBOLS FOR TURBOJET & TURBOPROP ENGINES



SYMBOLS

		Usual Dimensions
a.	Acoustic Velocity Linear acceleration	ft/sec, ft/sec^2
A.	Cross-section area	ft^2
c_p, c_v	Specific heats at constant pressure and volume	Btu/lb-°F
C.	Coefficient	None
D.	Diameter (D_t)	ft, in
E.	Energy	Btu, ft-lb
F, F_g, F_n.	Thrust, gross thrust, net thrust	lb
f.	Frequency	1/sec
g.	Acceleration due to gravity	ft/sec^2
h_s, h_{s2}, h_{t1}, h_{t2}. .	Specific static and total enthalpies	Btu/lb
h_f	Enthalpy of liquid fuel	Btu/lb
h.	Altitude	ft
J.	Mech. Equivalent of heat (778.26 ft-lb/Btu)	ft-lb/Btu
k, γ	Ratio of specific heats (c_p/c_v)	None
L.	Length	ft
m.	Mass	Slug, lb-sec^2/ft
M.	Moment or Torque	lb-ft
$M_1 M_2 M_3$	Mach Numbers (N_{Ma} also used)	None
n.	Rotational Speed Polytropic Exponent (pv^n = constant)	rpm, 1/min
N.	Dimensionless Number (N_{Ma}, N_{Re}, N_{Pr})	None
P.	Power[1] (P_g, P_t, P_c, P_e)	hp, ft-lb/sec, Btu/sec
P_{s1}, P_{s2}, P_{t1}, P_{t2}.	Static and total pressure	lb/in^2
q, q_c.	1/2 ρV^2, (P_t-P_s) respectively	lb/in^2
q.	Heat added (q_a) or rejected (q_r) or to work (q_w)	Bt./lb
Q.	Volume rate of flow	ft^3/sec
Q_p, Q_v, Q_H, Q_L, Q_f, Q_g.	Heating value at constant pressure, volume, higher, lower, liquid and gaseous	Btu/lb
R.	Reynolds number (N_{Re} also used)	None
R.	Gas Constant	ft-lb/lb-°F
r.	Radius	in, ft
s.	Specific entropy	Btu/lb-°F
t.	Time, Temperature (general) - Fahrenheit, Centigrade	sec, hr; °F, °C
T_{s1}, T_{s2}, T_{t1}, T_{t2}. .	Absolute Static and Total Temp.- Rankine, Kelvin	°R, °K
u.	Specific internal energy	Btu/lb
u, v, w.	Velocity Components	ft/sec
U.	Velocity, Rotor linear velocity (U_t)	ft/sec
v.	Specific volume	ft^3/lb
V.	Velocity, airspeed	ft/sec, mi/hr knots (nautical mi/hr)
w.	Weight rate of flow (w_a)	lb/sec, lb/hr
W.	Weight (Force)	lb
γ, k (Gamma, k) .	Ratio of specific heats (c_p/c_v)	None
δ_{am}, δ_{t2} (Delta)	Relative absolute pressures P_{am}/P_o, P_{t2}/P_o, (P_o = 29.92 in Hg)	None
Δ (Delta). . .	Finite difference (Δp) (Δh)	
η_g η_d η_c η_t .	(Eta). Efficiency of gears, diffuser, compressor turbine, exhaust nozzle, wake, thermal and fuel	None
η_m η_w η_{th} η_f		
η_o (Eta)	Overall efficiency = $\eta_f \times \eta_g \times \eta_p$ for jet engines, = $\eta_f \times \eta_g \times \eta_p$ for propeller drives	
θ_{am} θ_{t4} . .	(Theta). Relative absolute temperatures T_{am}/T_o, T_{t4}/T_o, (T_o = 518.4°R)	None
μ.	(Mu) . . Absolute viscosity	lb-sec/ft^2
ν.	(Nu) . . Kinematic viscosity	ft^2/sec
ρ.	(Rho). . Mass density (ρ_o = 0.002378 lb-sec^2/ft^4)	lb-sec^2/ft^4, slug/ft^3
σ.	(Sigma). Relative density (ρ / ρ_o)	None
ω.	(Omega). Angular velocity	radian/sec

SUBSCRIPTS

a. . . . Air (w_a), Axial (V_a), Added (q_a)
am . . . . Ambient (T_{am})
ab . . . . Afterburner (ΔP_{ab})
av . . . . Average (t_{av})
b. . . . Burner (η_b)
bl . . . . Bleed (C_{bl})
c. . . . Compressor (η_c), Compressible (q_c)
cr . . . . Critical (M_{cr}) (P_{cr})
d. . . . Diffuser (η_d), Duct (C_d), Discharge (C_d)
e. . . . Exhaust (η_e), Equivalent (F_e), Effective (A_e)
f. . . . Fuel (w_f), Fluid or Liquid (h_f)
F. . . . Thrust (C_F)
g. . . . Gas (w_g), Gross (F_g), Gaseous (Q_g), Gear (η_g)
h. . . . Heat exchanger (or intercooler), Hub (D_h)
H. . . . Higher (Q_H)
i. . . . Inlet (η_i), Indicated, (observed), (V_i)
j. . . . Jet (F_j)
L. . . . Lower (Q_L)
m. . . . Mean (D_m)
Ma . . . . Mach Number (N_{Ma})
n. . . . Exhaust nozzle (η_n), Net (F_n)
o. . . . Standard sea level, T_o = 518.4°R, P_o = 29.92 in Hg
p. . . . Exhaust pipe, Propeller (η_p), Constant pressure (c_p) (Q_p)
Pr . . . . Prandtl Number (N_{Pr})
Px . . . . Power extraction (C_{Px})
r. . . . Ram (η_r), Radial (V_r), Rejected (q_r)
Re . . . . Reynolds Number (N_{Re})
s. . . . Static (P_s), Shaft (P_s)
std. . . . Standard (T_{std}) (P_{std})
t. . . . Turbine (η_t), Total (Stagnation) (P_{t2}), Total (w_{ft}), Tip (V_t)
T. . . . Temperature (C_T)
th . . . . Thermal (η_{th}), Theoretical (V_{th})
u. . . . Tangential (V_u)
v. . . . Constant volume (c_v), Vel. coef. (C_v)
w. . . . Wall (T_w), Work (q_w), Wake (η_w), Flow Coef. (C_w)
1, 2, 3, . Stations as shown on above sketch (Avoid "0")

SUPERSCRIPTS

.(Prime) . Isentropic ($\Delta h'$) ($T_{s'}$)

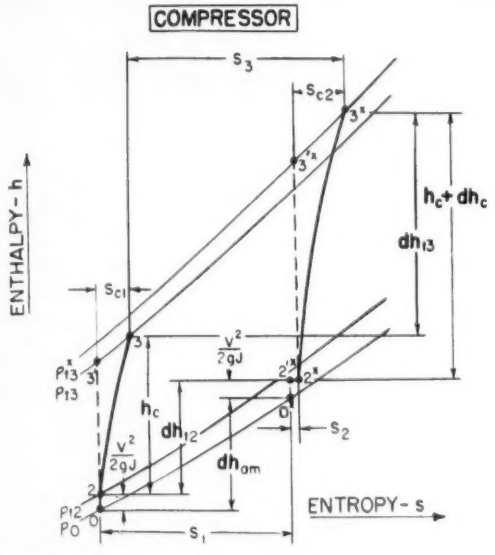
CORRECTED QUANTITIES

Quantity	Symbol Uncorrected	Corrected to Atmospheric Static Conditions	Corrected To P_{t2} and T_{t2}
Absolute Temperature (Any Temperature)	T	T/θ_{am}	T/θ_{t2}
Fuel-Air Ratio	w_f/w_a	$w_f/w_a\theta_{am}$	$w_f/w_a\theta_{t2}$
Rotational Speed	n	$n/\sqrt{\theta_{am}}$	$n/\sqrt{\theta_{t2}}$
Velocity (Any Velocity)	U	$U/\sqrt{\theta_{am}}$	$U/\sqrt{\theta_{t2}}$
Flight Speed	V	$V/\sqrt{\theta_{am}}$	$V/\sqrt{\theta_{t2}}$
Specific Fuel Consumption	w_f/F_n	$w_f/F_n\sqrt{\theta_{am}}$	$w_f/F_n\sqrt{\theta_{t2}}$
Specific Net Thrust	F_n/w_a	$F_n/w_a\sqrt{\theta_{am}}$	$F_n/w_a\sqrt{\theta_{t2}}$
Absolute Pressure (Any Pressure)	P	p/δ_{am}	p/δ_{t2}
Thrust (Any Thrust)	F	F/δ_{am}	F/δ_{t2}
Fuel Consumption	w_f	$w_f/\delta_{am}\sqrt{\theta_{am}}$	$w_f/\delta_{t2}\sqrt{\theta_{t2}}$
Horsepower (Any Horsepower)	hp	$hp/\delta_{am}\sqrt{\theta_{am}}$	$hp/\delta_{t2}\sqrt{\theta_{t2}}$
Air Flow	w_a	$w_a\sqrt{\theta_{am}}/\delta_{am}$	$w_a\sqrt{\theta_{t2}}/\delta_{t2}$
Exhaust Nozzle Area Ratio	A_7/A_6		

1 Although capital P is the ASA Symbol for power the following abbreviations can be used on curves to avoid confusion with small p for pressure:

thp, shp, nhp, fhp, eshp. . . . . Thrust, Shaft, Net, Friction, Equivalent Shaft Horsepower

FIG. 14 SYMBOLS



FROM COMPRESSOR DIAGRAM

$$s_1 = \frac{dh_{am}}{T_{am}} = \frac{dh_{12}}{T_{12}} - \frac{v_{12}(dP_{12})_{TEMP}}{T_{12}} = \frac{dh_{12}}{T_{12}} - \frac{R}{J}\left(\frac{dP_{12}}{P_{12}}\right)_{TEMP} \quad (1)$$

SINCE $dV = 0$ DURING CORRECTION

$$h_{12} - h_{am} = \frac{V^2}{2gJ} = h'_{12} - h'_{am}$$

THEREFORE

$$dh_{am} = dh_{12} \quad (1a)$$

FROM EQ (1)

$$\frac{R}{J}\left(\frac{dP_{12}}{P_{12}}\right)_{TEMP} = \frac{dh_{12}}{T_{12}} - \frac{dh_{am}}{T_{am}} = \frac{dh_{am}}{T_{am}}\left(\frac{T_{am}}{T_{12}} - 1\right) \quad (1b)$$

$$s_2 = -\frac{v_{12}(dP_{12})_d}{J T_{12}} = -\frac{R}{J}\left(\frac{dP_{12}}{P_{12}}\right)_d \quad (2)$$

$$s_3 = \frac{dh_{13}}{T_{13}} - \frac{v_{13}\,dP_{13}}{J T_{13}} = \frac{dh_{13}}{T_{13}} - \frac{R}{J}\left(\frac{dP_{13}}{P_{13}}\right) \quad (3)$$

SINCE $\frac{w_g\sqrt{T_{14}}}{P_{14}} = \text{CONSTANT}$

$$\frac{dw_g}{w_g} + \frac{dT_{14}}{2T_{14}} - \frac{dP_{14}}{P_{14}} = 0 \quad (3a)$$

AND ALSO SINCE $\frac{\Delta P_b}{P_{13}} = 1 - \frac{P_{14}}{P_{13}} = \text{CONSTANT}$

$$\frac{dP_{14}}{P_{14}} = \frac{dP_{13}}{P_{13}} = \frac{dw_g}{w_g} + \frac{dT_{14}}{2T_{14}} \quad (3b)$$

$$s_{c1} = \frac{h_c(1-\eta_c)}{T_{13}} \quad (4)$$

$$s_{c2} = \frac{(h_c + dh_c)(1-\eta_c)}{T_{13}} \quad (5)$$

$$s_1 + s_2 + s_{c2} = s_3 + s_{c1} \quad (6)$$

$$\frac{dh_{12}}{T_{12}} - \frac{dh_{am}}{T_{am}}\left(\frac{T_{am}}{T_{12}} - 1\right) - \frac{R}{J}\left(\frac{dP_{12}}{P_{12}}\right)_d + \frac{(h_c + dh_c)(1-\eta_c)}{T_{13}} = \frac{dh_{13}}{T_{13}} - \frac{R}{J}\frac{dw_g}{w_g} - \frac{R}{2J}\frac{dT_{14}}{T_{14}} + \frac{h_c(1-\eta_c)}{T_{13}}$$

SINCE $dh_c = dh_{13} - dh_{12}$

$$\frac{dT_{13}}{T_{13}} = \frac{1}{\eta_c}\left[1 - \frac{(1-\eta_c)T_{am}}{T_{13}}\right]\frac{dT_{am}}{T_{am}} - \frac{k-1}{k\eta_c}\left(\frac{dP_{12}}{P_{12}}\right)_d + \frac{k-1}{k\eta_c}\frac{dw_g}{w_g} + \frac{k-1}{2k\eta_c}\frac{dT_{14}}{T_{14}} \quad (7)$$

ALSO

$$dh_c = \frac{c_p T_{am}}{\eta_c}\left(\frac{T_{13}}{T_{am}} - 1\right)\frac{dT_{am}}{T_{am}} - \frac{k-1}{k\eta_c}c_p T_{13}\left(\frac{dP_{12}}{P_{12}}\right)_d + \frac{k-1}{k\eta_c}c_p T_{13}\frac{dw_g}{w_g} + \frac{k-1}{2k\eta_c}c_p T_{13}\frac{dT_{14}}{T_{14}} \quad (8)$$

FROM A POWER BALANCE WE OBTAIN

$$w_a h_c + \text{SHP}\,\frac{2545}{3600} = w_g h_1 \quad (9)$$

DIFFERENTIATING AND DIVIDING BY w_a

$$h_c\frac{dw_a}{w_a} + dh_c + \frac{2545\,HP_{EXT}}{3600\,w_a} = h_1\frac{dw_g}{w_g} + dh_1$$

THIS ASSUMES $\frac{w_a}{w_g} = 1$ AND $dSHP = HP_{EXT}$

SUBSTITUTING FOR dh_c FROM EQ (8) WE HAVE

$$dh_1 = h_c\frac{dw_a}{w_a} + \left[\frac{k-1}{k\eta_c}c_p T_{13} - h_1\right]\frac{dw_g}{w_g} + \frac{2545\,HP_{EXT}}{3600\,w_a} - \frac{k-1}{k\eta_c}c_p T_{13}\left(\frac{dP_{12}}{P_{12}}\right)_d + \frac{k-1}{2k\eta_c}c_p T_{13}\frac{dT_{14}}{T_{14}} + \frac{c_p T_{am}}{\eta_c}\left(\frac{T_{13}}{T_{am}} - 1\right)\frac{dT_{am}}{T_{am}} \quad (10)$$

ASSUMING $w_a - w_g = w_{bl}$ AND $dw_a = (dw_a)_T + (dP_{12})_d$

AND $dh_1 = dh_{14} - dh_{15}$

$$\frac{dT_{15}}{T_{15}} = -\frac{k-1}{k\eta_c}\frac{T_{13}}{T_{15}}\left(\frac{dw_a}{w_a}\right)_T - \frac{2545\,HP_{REF}}{3600\,c_p T_{15}\,w_a}\frac{HP_{EXT}}{HP_{REF}} - \frac{T_{am}}{\eta_c T_{15}}\left(\frac{T_{13}}{T_{am}} - 1\right)\frac{dT_{am}}{T_{am}} - \left[\frac{h_1}{c_p T_{15}} - \frac{k-1}{k\eta_c}\frac{T_{13}}{T_{15}}\right]\frac{w_{bl}}{w_a} + \left[\frac{T_{14}}{T_{15}} - \frac{k-1}{2k\eta_c}\frac{T_{13}}{T_{15}}\right]\frac{dT_{14}}{T_{14}} \quad (11)$$

THIS ASSUMES ALSO $h_c\frac{dw_a}{w_a} - h_1\frac{dw_a}{w_a} = 0$ TO AVOID SECOND ORDER TERMS. THE TERM HP_{REF} IS INTRODUCED TO PROVIDE A DIMENSIONLESS COEFFICIENT. IT IS ARBITRARILY TAKEN AS TEN PERCENT (10%) OF THE SEA LEVEL STATIC MILITARY JET HORSEPOWER

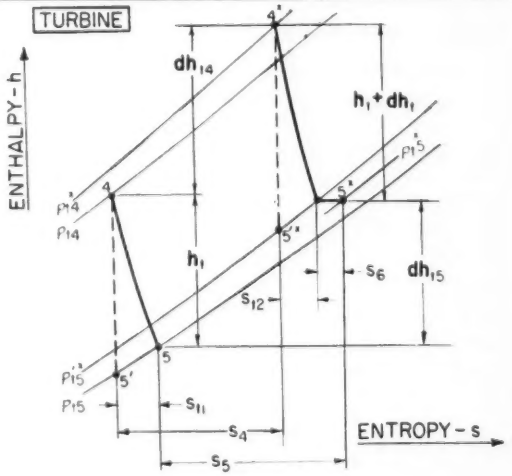


FIG. 15 DEVELOPMENT OF EQUATIONS

FROM TURBINE DIAGRAM

$$s_4 = \frac{dh_{t4}}{T_{t4}} - \frac{v_{t4}\,dP_{t4}}{J\,T_{t4}} = \frac{dh_{t4}}{T_{t4}} - \frac{R}{J}\frac{dP_{t4}}{P_{t4}} \tag{12}$$

$$s_5 = \frac{dh_{t5}}{T_{t5}} - \frac{v_{t5}\,dP_{t5}}{J\,T_{t5}} = \frac{dh_{t5}}{T_{t5}} - \frac{R}{J}\frac{dP_{t5}}{P_{t5}} \tag{13}$$

$$s_{11} = \frac{h_t}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right) \tag{14}$$

$$s_{12} = \frac{h_t + dh_t}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right) \tag{15}$$

$$s_6 = -\frac{v_{t5}(dP_{t5})_d}{J\,T_{t5}} = -\frac{R}{J}\left(\frac{dP_{t5}}{P_{t5}}\right)_d \tag{16}$$

$$s_4 + s_{12} + s_6 - s_{11} = s_5 \tag{17}$$

$$\frac{dh_{t4}}{T_{t4}} - \frac{R}{J}\frac{dP_{t4}}{P_{t4}} + \frac{h_t + dh_t}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right) - \frac{R}{J}\left(\frac{dP_{t5}}{P_{t5}}\right)_d - \frac{h_t}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right) = \frac{dh_{t5}}{T_{t5}} - \frac{R}{J}\frac{dP_{t5}}{P_{t5}} \tag{18}$$

SUBSTITUTING $dh_t = dh_{t4} - dh_{t5}$ AND $\frac{dP_{t4}}{P_{t4}} = \frac{dw_g}{w_g} + \frac{dT_{t4}}{2T_{t4}}$ WE OBTAIN

$$\frac{dP_{t5}}{P_{t5}} = \frac{dw_g}{w_g} + \left(\frac{dP_{t5}}{P_{t5}}\right)_d + \frac{k\,dT_{t5}}{(k-1)\eta_t T_{t5}} - \left(\frac{k}{k-1} - \frac{1}{2} + \frac{k}{(k-1)}\frac{T_{t4}}{T_{t5}}\frac{(1-\eta_t)}{\eta_t}\right)\frac{dT_{t4}}{T_{t4}} \tag{19}$$

SUBSTITUTING FOR $\frac{dT_{t5}}{T_{t5}}$ FROM EQ(11) THEN

$$\frac{dP_{t5}}{P_{t5}} = \left[1 - \frac{T_{t3}}{\eta_t\,\eta_c T_{t5}}\right]\left(\frac{dw_a}{w_a}\right)_T - \frac{2545\,HP_{REF}\,J}{3600\,\eta_t\,T_{t5}\,R\,w_a}\left(\frac{HP_{EXT}}{HP_{REF}}\right) - \left[1 + \frac{J\,h_t}{R\,\eta_t T_{t5}} - \frac{T_{t3}}{\eta_c\eta_t T_{t5}}\right]\left(\frac{w_{bl}}{w_a}\right) + \left(\frac{dP_{t2}}{P_{t2}}\right)_d + \left(\frac{dP_{t5}}{P_{t5}}\right)_d - \frac{k\,T_{am}}{(k-1)\eta_c\eta_t T_{t5}}\left(\frac{T_{t3}}{T_{am}} - 1\right)\frac{dT_{am}}{T_{am}} + \left[\frac{1}{2} - \frac{k}{k-1} + \frac{k\,T_{t4}}{(k-1)\,T_{t5}} - \frac{T_{t3}}{2\eta_c\eta_t T_{t5}}\right]\frac{dT_{t4}}{T_{t4}} \tag{20}$$

TO OBTAIN THE VARIATION OF EXHAUST AREA WE ASSUME

$$\frac{w_g\sqrt{T_{t5}}}{P_{t5}A} = \text{CONSTANT} \tag{21}$$

BY DIFFERENTIATING

$$\frac{dA}{A} = \frac{dw_g}{w_g} + \frac{dT_{t5}}{2T_{t5}} - \frac{dP_{t5}}{P_{t5}} \tag{22}$$

THE COEFFICIENTS OF THIS EQUATION COMBINED WITH EQUATIONS (11) AND (20) ARE SHOWN ON FIG. 18

THE VARIATION OF THRUST IS DERIVED AS FOLLOWS

$$F_n = F_g - F_r \tag{23}$$

DIFFERENTIATING

$$\frac{dF_n}{F_n} = \frac{F_g\,dF_g}{F_n\,F_g} - \frac{F_r\,dF_r}{F_n\,F_r} \tag{24}$$

BUT $F_g = \frac{w_g c}{g}$ AND $\frac{dF_g}{F_g} = \frac{dw_g}{w_g} + \frac{dc}{c}$

ALSO $F_r = \frac{w_a V}{g}$ AND $\frac{dF_r}{F_r} = \frac{dw_a}{w_a}$ SINCE $\frac{dV}{V} = 0$

ASSUMING

$$\frac{dw_a}{w_a} - \frac{dw_g}{w_g} = \frac{w_{bl}}{w_a} \quad \text{AND} \quad \frac{dw_a}{w_a} = \left(\frac{dw_a}{w_a}\right)_T + \left(\frac{dP_{t2}}{P_{t2}}\right)_d \tag{25}$$

THEREFORE EQ (24) BECOMES

$$\frac{dF_n}{F_n} = \frac{F_g}{F_n}\left(-\frac{w_{bl}}{w_a} + \frac{dc}{c}\right) + \left(\frac{dw_a}{w_a}\right)_T + \left(\frac{dP_{t2}}{P_{t2}}\right)_d \tag{26}$$

BUT $\frac{c^2}{2gJ} = \eta_n h'_n$ THEREFORE $\frac{dc}{c} = \frac{dh'_n}{2h'_n}$

AND SINCE

$$h'_n = c_p T_{t5}\left(1 - \frac{T'_{s7}}{T_{t5}}\right) = c_p T_{t5}\left[1 - \left(\frac{P_{am}}{P_{t5}}\right)^{\frac{k-1}{k}}\right]$$

THEREFORE

$$\frac{dh'_n}{h'_n} = \frac{2\,dc}{c} = \frac{dT_{t5}}{T_{t5}} + \frac{RT'_{s7}}{J h'_n}\frac{dP_{t5}}{P_{t5}} \tag{27}$$

COMBINING EQS (26) AND (27) WE HAVE

$$\frac{dF_n}{F_n} = \frac{F_g}{F_n}\left(-\frac{w_{bl}}{w_a} + \frac{dT_{t5}}{2T_{t5}} + \frac{RT'_{s7}}{2J h'_n}\frac{dP_{t5}}{P_{t5}}\right) + \left(\frac{dw_a}{w_a}\right)_T + \left(\frac{dP_{t2}}{P_{t2}}\right)_d \tag{28}$$

THE COEFFICIENTS OF THIS EQUATION IN COMPLETE FORM ARE SHOWN ON FIG. 18

THE CORRESPONDING FUEL FLOW VARIATION IS AS SHOWN BELOW

$$w_f = \frac{(h_{t4} - h_{t3})\,w_g\,3600}{\eta_b\,q_f} \tag{29}$$

$$\frac{dw_f}{w_f} = \frac{dw_g}{w_g} + \frac{dh_{t4} - dh_{t3}}{h_b}\left(1 + \frac{dw_g}{w_g}\right) \tag{30}$$

THE SECOND ORDER TERM WAS RETAINED TO PROVIDE DESIRED ACCURACY

EQ (30) MAY BE REWRITTEN AS (31)

$$\frac{dw_f}{w_f} = \left(\frac{dw_a}{w_a}\right)_T + \left(\frac{dP_{t2}}{P_{t2}}\right)_d - \frac{w_{bl}}{w_a} + \left[\frac{c_p T_{t4}}{h_b}\frac{dT_{t4}}{T_{t4}} - \frac{c_p T_{t3}}{h_b}\frac{dT_{t3}}{T_{t3}}\right]\left(1 + \frac{dw_g}{w_g}\right)$$

THE VARIATION OF THRUST FOR AN ENGINE WITH OPERATING AFTERBURNER IS AS FOLLOWS

$$dh_{t6} = dh_{t5} + dh_{ab} \tag{32}$$

WHERE $h_{ab} = \frac{w_f}{w_g} Q_f \eta_{ab}$ (33)

DIFFERENTIATING

$$\frac{dh_{ab}}{h_{ab}} = \frac{d\eta_{ab}}{\eta_{ab}} + \frac{d\left(\frac{w_f}{w_g}\right)}{w_f/w_g} \tag{34}$$

ASSUMING

$$\eta_{ab} = (P_{t5}, T_{t5}, \frac{w_f}{w_g})$$

THEN

$$\frac{d\eta_{ab}}{\eta_{ab}} = \left[\frac{\frac{\partial \eta_{ab}}{\eta_{ab}}}{\frac{\partial P_{t5}}{P_{t5}}}\right]\frac{dP_{t5}}{P_{t5}} + \left[\frac{\frac{\partial \eta_{ab}}{\eta_{ab}}}{\frac{\partial T_{t5}}{T_{t5}}}\right]\frac{dT_{t5}}{T_{t5}} + \left[\frac{\frac{\partial \eta_{ab}}{\eta_{ab}}}{\frac{\partial w_f/w_g}{w_f/w_g}}\right]\frac{d\left(\frac{w_f}{w_g}\right)}{w_f/w_g} \tag{35}$$

SINCE $\frac{\Delta P_{ab}}{P_{t5}}$ IS ASSUMED CONSTANT THEN

$$\frac{\Delta P_{t6}}{P_{t6}} = \frac{\Delta P_{t5}}{P_{t5}} \tag{36}$$

EQUATION (28) REWRITTEN FOR OPERATING AFTERBURNER BECOMES

$$\frac{dF_n}{F_n} = \frac{F_g}{F_n}\left(-\frac{w_{bl}}{w_a} + \frac{dT_{t6}}{2T_{t6}} + \frac{RT'_{s7}}{2J h'_n}\frac{dP_{t6}}{P_{t6}}\right) + \left(\frac{dw_a}{w_a}\right)_T + \left(\frac{dP_{t2}}{P_{t2}}\right)_d \tag{37}$$

THIS EQUATION COMBINED WITH EQUATIONS (32) TO (36) BECOMES

FIG. 16 DEVELOPMENT OF EQUATIONS (CON'T)

$$\frac{\Delta F_n}{F_n} = \frac{F_g}{F_n}\left(-\frac{w_{bl}}{w_a} + \frac{T_{t5}}{2T_{t6}}\frac{dT_{t5}}{T_{t5}} + \frac{\Delta T_{ab}}{2T_{t6}}\left[\frac{\frac{\partial \eta_{ab}}{\eta_{ab}}}{\frac{\partial P_{t5}}{P_{t5}}}\right]\frac{dP_{t5}}{P_{t5}} + \frac{\Delta T_{ab}}{2T_{t6}}\left[\frac{\frac{\partial \eta_{ab}}{\eta_{ab}}}{\frac{\partial T_{t5}}{T_{t5}}}\right]\frac{dT_{t5}}{T_{t5}}\right.$$

$$\left. + \frac{\Delta T_{ab}}{2T_{t6}}\left(1 + \left[\frac{\frac{\partial \eta_{ab}}{\eta_{ab}}}{\frac{\partial w_f/w_g}{w_f/w_g}}\right]\right)\frac{d\left(\frac{w_f}{w_g}\right)}{w_f/w_g} + \frac{RT_{s7}'}{2Jh_n'}\frac{\Delta P_{t5}}{P_{t5}}\right) + \left(\frac{dw_a}{w_a}\right)_1 + \left(\frac{dP_{t2}}{P_{t2}}\right)_d \quad (38)$$

THIS EQUATION MAY BE SOLVED FOR ANY PARTICULAR CONTROL, USING THE EQUATIONS ON FIG 18, TO OBTAIN THE CORRECTION FACTOR COEFFICIENTS SIMILAR TO THOSE FOR THE BASIC ENGINE

THE CORRESPONDING AFTERBURNER AND TOTAL FUEL FLOW VARIATION IS GIVEN BELOW

$$\left(\frac{dw_f}{w_f}\right)_{ab} = \frac{dw_a}{w_a} + \frac{d\left(\frac{w_f}{w_g}\right)}{w_f/w_g}\left(1 + \frac{dw_g}{w_g}\right) \quad (39)$$

SUBSTITUTING EQ (25) WE FIND

$$\left(\frac{dw_f}{w_f}\right)_{ab} = \left(\frac{dw_a}{w_a}\right)_T + \left(\frac{dP_{t2}}{P_{t2}}\right)_d - \frac{w_{bl}}{w_a} + \frac{d\left(\frac{w_f}{w_g}\right)}{w_f/w_g}\left(1 + \frac{dw_g}{w_g}\right) \quad (40)$$

THE VARIATION OF TOTAL FUEL FLOW IS

$$\left(\frac{dw_f}{w_f}\right)_t = \frac{w_{f\,be}}{w_{f\,t}}\left(\frac{dw_f}{w_f}\right)_{be} + \frac{w_{f\,ab}}{w_{f\,t}}\left(\frac{dw_f}{w_f}\right)_{ab} \quad (41)$$

THE SUBSCRIPT be DESIGNATES THE BASIC ENGINE

COMBINING EQS (31), (40) AND (41) WE OBTAIN

$$\left(\frac{dw_f}{w_f}\right)_t = \left(\frac{dw_a}{w_a}\right)_T + \left(\frac{dP_{t2}}{P_{t2}}\right)_d - \frac{w_{bl}}{w_a} + \frac{w_{f\,be}}{w_{f\,t}}\frac{dh_{t4} - dh_{t3}}{h_b}\left(1 + \frac{dw_g}{w_g}\right)$$

$$+ \frac{w_{f\,ab}}{w_{f\,t}}\frac{d\left(\frac{w_f}{w_g}\right)}{w_f/w_g}\left(1 + \frac{dw_g}{w_g}\right) \quad (42)$$

THIS EQUATION CAN BE SOLVED FOR ANY PARTICULAR CONTROL USING THE EQUATIONS ON FIG. 18

THE VARIATION OF AIR FLOW CAN BE DETERMINED AS FOLLOWS

FOR ANY TURBOJET ENGINE

$$\Gamma \equiv \left(\frac{w_a\sqrt{\theta_{t2}}}{\delta_{t2}}\right) = f\left(\frac{n}{\sqrt{\theta_{t2}}}\right) \quad (43)$$

THIS RELATION NEGLECTS VARIATIONS DUE TO COMPRESSOR PRESSURE RATIO

FROM THIS KNOWN FUNCTION IT IS POSSIBLE TO PLOT

$$\frac{\Delta\Gamma}{\Gamma} = f\left(\Gamma, \frac{dT_{t2}}{T_{t2}}\right) \quad (44)$$

FROM EQ (43) WE FIND

$$\frac{d\Gamma}{\Gamma} = \frac{dw_a}{w_a} + \frac{dT_{t2}}{2\,T_{t2}} - \frac{dP_{t2}}{P_{t2}} \quad (45)$$

FOR CONSTANT FLIGHT SPEED A CHANGE IN AMBIENT TEMPERATURE RESULTS IN A CHANGE IN P_{t2} AS DOES A DUCT LOSS

EQ (45) MAY BE REWRITTEN AS

$$\frac{d\Gamma}{\Gamma} = \frac{dw_a}{w_a} + \frac{dT_{t2}}{2T_{t2}} - \left(\frac{dP_{t2}}{P_{t2}}\right)_1 - \left(\frac{dP_{t2}}{P_{t2}}\right)_d \quad (46)$$

FROM EQS (1) AND (1b) WE SEE

$$\frac{dw_a}{w_a} = \frac{d\Gamma}{\Gamma} - \frac{T_{am}}{2T_{t2}}\frac{dT_{am}}{T_{am}} + \frac{k}{k-1}\left(\frac{T_{am}}{T_{t2}} - 1\right)\frac{dT_{am}}{T_{am}} + \left(\frac{dP_{t2}}{P_{t2}}\right)_d \quad (47)$$

COMBINING TERMS

$$\frac{dw_a}{w_a} = \frac{d\Gamma}{\Gamma} - \frac{T_{am}}{T_{t2}}\left(\frac{1}{2} - \frac{k}{k-1} + \frac{k\,T_{t2}}{k-1\,T_{am}}\right)\frac{dT_{am}}{T_{am}} + \left(\frac{dP_{t2}}{P_{t2}}\right)_d \quad (48)$$

BUT

$$\frac{T_{t2}}{T_{am}} = \left(\frac{k-1}{2}M_o^2 + 1\right) \quad \text{WHERE } M_o = \text{FREE STREAM MACH NO}$$

EQ (48) BECOMES

$$\frac{dw_a}{w_a} = \frac{d\Gamma}{\Gamma} - \left[\frac{M_o^2\frac{k}{2} + \frac{1}{2}}{M_o^2\frac{k-1}{2} + 1}\right]\frac{dT_{am}}{T_{am}} + \left(\frac{dP_{t2}}{P_{t2}}\right)_d \quad (49)$$

SINCE

$$\frac{dw_a}{w_a} - \frac{dw_g}{w_g} = \frac{w_{bl}}{w_a}$$

WE FIND

$$\frac{dw_g}{w_g} = \frac{d\Gamma}{\Gamma} - \left[\frac{M_o^2\frac{k}{2} + \frac{1}{2}}{M_o^2\frac{k-1}{2} + 1}\right]\frac{dT_{am}}{T_{am}} + \left(\frac{dP_{t2}}{P_{t2}}\right)_d - \frac{w_{bl}}{w_a} \quad (50)$$

FIG. 17 DEVELOPMENT OF EQUATIONS (CONCLUDED)

by presenting engine performance corrected to the compressor inlet total pressure. In this way the airplane designer could readily allow for inlet losses by combining the performance of his inlet duct with that of the engine.

The next difficulty to present itself was the question of how to allow for exhaust duct extension losses. This difficulty could be overcome by presenting a so-called "hot gas generator" performance.

This method consisted of presenting the gas flow and temperature leaving the turbine in terms of the engine pressure ratio (p_{t6}/p_{t2}) and the corrected engine speed. Using this method, the airplane designer could combine the performance of the generator with the performance of the inlet and exhaust ducting and the performance of the exhaust nozzle to obtain the engine thrust. Several new difficulties with the above scheme soon became apparent.

(1) There was a great amount of calculation required before one arrived at the estimated engine thrust. Therefore, there could be a question of consistency of estimated thrust between the various airplane companies.

(2) The corrected quantities were intelligible to only a relatively few people.

(3) It was difficult to indicate the engine operating limits and maximum rotational speeds.

(4) Altitude or Reynolds Number or specific heat effects could not be easily handled by the method.

(5) The effects of air bleeding or power extraction could not be easily handled.

The present method was devised after tests on the effect of air bleeding and duct losses agreed closely with calculations using the method.

It was found that expressions for correction factors could be developed which depended on quantities already known from the cycle calculations used to determine the estimated engine performance. This meant that correction factors could be calculated without recalculating cycles including the losses. Although the method assumes that the corrections are proportional

	INLET DUCT LOSS $\left(\frac{\Delta P_{t2}}{P_{t2}}\right)_d$ *	EXHAUST DUCT LOSS $\left(\frac{\Delta P_{t5}}{P_{t5}}\right)_d$ *	AIR BLEED $\left(\frac{w_{bl}}{w_a}\right)$	POWER EXTRACTION $\left(\frac{HP_{EXT}}{HP_{REF}}\right)$	AMBIENT TEMPERATURE VARIATION $\left(\frac{\Delta T_{am}}{T_{am}}\right)$	$\left(\frac{\Delta w_a}{w_a}\right)_T$	TURBINE INLET TEMP. VARIATION $\left(\frac{\Delta T_{t4}}{T_{t4}}\right)$
$\frac{\Delta F_n}{F_n}$ * EQ (28)	$1+\frac{F_g R T_{t7}'}{F_n J 2 h_n'}$	$\frac{F_g R T_{t7}'}{F_n J 2 h_n'}$	$\frac{F_g}{F_n}\left\{1+\frac{R T_{t7}'}{2 J h_n'}+\frac{1}{2 h_n'}\left[h_t-\frac{R T_{t3}}{J\eta_c}\right]\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]\right\}$	$\frac{F_g 2545\, HP_{REF}}{F_n 3600\, w_a 2 h_n'}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]$	$\frac{F_g c_p T_{am}}{F_n 2\eta_c h_n'}\left[\frac{T_{t3}}{T_{am}}-1\right]\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]$	$-1-\frac{F_g}{F_n 2 h_n'}\left\{\frac{R T_{t7}'}{J}-\frac{R T_{t3}}{J\eta_c}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]\right\}$	$-\frac{F_g}{F_n 2 h_n'}\left\{c_p T_{t4}-\frac{R T_{t7}'}{2J}\left(\frac{k+1}{k-1}\right)-\frac{R T_{t3}}{2J\eta_c}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]\right\}$
$\frac{\Delta w_f}{w_f}$ * EQ (31)	1	0	$1+\frac{R T_{t3}}{J\eta_c h_b}\left[1+\frac{\Delta w_a}{w_a}\right]$	0	$\frac{c_p T_{am}}{\eta_c h_b}\left[\frac{T_{t3}}{T_{am}}-1+\eta_c\right]\left[1+\frac{\Delta w_a}{w_a}\right]$	$-1+\frac{R T_{t3}}{J\eta_c h_b}\left[1+\frac{\Delta w_a}{w_a}\right]$	$-\left[\frac{c_p T_{t4}}{h_b}-\frac{R T_{t3}}{2 J\eta_c h_b}\right]\left[1+\frac{\Delta w_a}{w_a}\right]$
$\frac{\Delta T_{t3}}{T_{t3}}$ EQ(7)	0	0	$-\frac{k-1}{k\eta_c}$	0	$\frac{1}{\eta_c}\left[1-\frac{(1-\eta_c)T_{am}}{T_{t3}}\right]$	$\frac{k-1}{k\eta_c}$	$\frac{k-1}{k\eta_c}$
$\frac{\Delta P_{t3}}{P_{t3}}$ EQ(3b)	-1	0	-1	0	0	1	$\frac{1}{2}$
$\frac{\Delta T_{t5}}{T_{t5}}$ EQ(11)	0	0	$-\frac{h_t}{c_p T_{t5}}+\frac{(k-1)T_{t3}}{k\eta_c T_{t5}}$	$-\frac{2545\, HP_{REF}}{3600\, w_a c_p T_{t5}}$	$-\frac{T_{am}}{\eta_c T_{t5}}\left[\frac{T_{t3}}{T_{am}}-1\right]$	$-\frac{(k-1)T_{t3}}{k\eta_c T_{t5}}$	$\frac{T_{t4}}{T_{t5}}-\frac{(k-1)T_{t3}}{k 2\eta_c T_{t5}}$
$\frac{\Delta P_{t5}}{P_{t5}}$ EQ(20)	-1	-1	$-1-\frac{J h_t}{R\eta_t T_{t5}}+\frac{T_{t3}}{\eta_c\eta_t T_{t5}}$	$-\frac{2545\, J\, HP_{REF}}{3600\, w_a R\eta_t T_{t5}}$	$-\frac{k T_{am}}{(k-1)\eta_c\eta_t T_{t5}}\left[\frac{T_{t3}}{T_{am}}-1\right]$	$1-\frac{T_{t3}}{\eta_c\eta_t T_{t5}}$	$\frac{T_{t4}}{T_{t5}}\frac{k}{k-1}-\frac{T_{t3}}{2\eta_c\eta_t T_{t5}}+\frac{1}{2}-\frac{k}{k-1}$
$\frac{\Delta A}{A}$ EQ(22)	0	1	$\left[\frac{k-1}{k\eta_c}\frac{T_{t3}}{T_{t5}}-\frac{h_t}{c_p T_{t5}}\right]\left[\frac{1}{2}-\frac{k}{(k-1)\eta_t}\right]$	$-\frac{2545\, HP_{REF}}{3600\, w_a c_p T_{t5}}\left[\frac{1}{2}-\frac{k}{(k-1)\eta_t}\right]$	$-\frac{T_{am}}{\eta_c T_{t5}}\left[\frac{T_{t3}}{T_{am}}-1\right]\left[\frac{1}{2}-\frac{k}{(k-1)\eta_t}\right]$	$-\frac{(k-1)T_{t3}}{k\eta_c T_{t5}}\left[\frac{1}{2}-\frac{k}{(k-1)\eta_t}\right]$	$-\left[\frac{T_{t4}}{T_{t5}}-1\right]\frac{k+1}{2(k-1)}-\frac{(k-1)T_{t3}}{2k\eta_c T_{t5}}\left[\frac{1}{2}-\frac{k}{(k-1)\eta_t}\right]$
$\frac{\Delta w_a}{w_a}$ EQ (25)	-1	0	-1	0	0	1	0

* THE SIGNS OF THE COEFFICIENTS HAVE BEEN CHANGED SO THAT A DECREASE OF THESE QUANTITIES IS POSITIVE

FIG. 18 GENERAL CORRECTION EQUATIONS

	INLET DUCT LOSS $\left(\frac{\Delta P_{t2}}{P_{t2}}\right)_d$ *	EXHAUST DUCT LOSS $\left(\frac{\Delta P_{t5}}{P_{t5}}\right)_d$ *	AIR BLEED $\left(\frac{w_{bl}}{w_a}\right)$	POWER EXTRACTION $\left(\frac{HP_{EXT}}{HP_{REF}}\right)$	AMBIENT TEMPERATURE VARIATION $\left(\frac{\Delta T_{am}}{T_{am}}\right)$	$\left(\frac{\Delta w_a}{w_a}\right)_T$	CONTROL
$\frac{\Delta F_n}{F_n}$ *	$\overbrace{1+C_d}$ / $1+\frac{F_g R T_{t7}'}{F_n 2 J h_n'}$	$\overbrace{C_d}$ / $\frac{F_g R T_{t7}'}{F_n 2 J h_n'}$	$\overbrace{C_{bl}}$ / $\frac{F_g}{F_n}\left\{1+\frac{R T_{t7}'}{2 J h_n'}+\frac{1}{2 h_n'}\left[h_t-\frac{R T_{t3}}{J\eta_c}\right]\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]\right\}$	$\overbrace{C_{px}}$ / $\frac{F_g 2545\, HP_{REF}}{F_n 3600\, w_a 2 h_n'}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]$	$\overbrace{C_{T_1}}$ / $\frac{F_g c_p T_{am}}{F_n 2\eta_c h_n'}\left[\frac{T_{t3}}{T_{am}}-1\right]\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]$	$\overbrace{C_{T_2}}$ / $-1-\frac{F_g}{F_n 2 h_n'}\left\{\frac{R T_{t7}'}{J}-\frac{R T_{t3}}{J\eta_c}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]\right\}$	CONSTANT TURBINE INLET TEMPERATURE $\frac{\Delta T_{t4}}{T_{t4}}=0$
$\frac{\Delta w_f}{w_f}$ *	$\overbrace{1}$ / 1	$\overbrace{C_d'}$ / 0	$\overbrace{1+C_{bl}'\left(1+\frac{w_{bl}}{w_a}\right)}$ / $1+\frac{R T_{t3}}{J\eta_c h_b}\left[1+\frac{w_{bl}}{w_a}\right]$	$\overbrace{C_{px}'}$ / 0	$\overbrace{C_{T_1}'\left(1+\frac{\Delta w_a}{w_a}\right)}$ / $\frac{c_p T_{am}}{\eta_c h_b}\left[\frac{T_{t3}}{T_{am}}-1+\eta_c\right]\left[1+\frac{\Delta w_a}{w_a}\right]$	$\overbrace{-1+C_{T_2}'\left(1+\frac{\Delta w_a}{w_a}\right)}$ / $-1+\frac{R T_{t3}}{J\eta_c h_b}\left[1+\frac{\Delta w_a}{w_a}\right]$	
$\frac{\Delta F_n}{F_n}$ *	$\overbrace{1+C_d}$ / $1+\frac{F_g R T_{t7}'}{F_n 2 J h_n'}$	$\overbrace{C_d}$ / $\frac{F_g R T_{t7}'}{F_n 2 J h_n'}$	$\overbrace{C_{bl}}$ / $\frac{F_g}{F_n}\left\{1+\frac{R T_{t7}'}{2 J h_n'}+\frac{B}{2 h_n'}\left[h_t-\frac{R T_{t3}}{J\eta_c}\right]\right\}$	$\overbrace{C_{px}}$ / $\frac{F_g 2545\, HP_{REF}\, B}{F_n 3600\, w_a 2 h_n'}$	$\overbrace{C_{T_1}}$ / $\frac{F_g c_p T_{am}}{F_n 2\eta_c h_n'}\left(\frac{T_{t3}}{T_{am}}-1\right)B$	$\overbrace{C_{T_2}}$ / $-1-\frac{F_g}{F_n 2 h_n'}\left[\frac{R T_{t7}'}{J}-\frac{R T_{t3}B}{J\eta_c}\right]$	CONSTANT TURBINE OUTLET TEMP. $\frac{\Delta T_{t5}}{T_{t5}}=0$
$\frac{\Delta w_f}{w_f}$ *	$\overbrace{1}$ / 1	$\overbrace{C_d'}$ / 0	$\overbrace{1+C_{bl}'\left(1+\frac{w_{bl}}{w_a}\right)}$ / $1-\frac{1}{h_b}\left[h_t-\frac{2 R T_{t3}}{J\eta_c h_b}\right]\left[1+\frac{w_{bl}}{w_a}\right]$	$\overbrace{C_{px}'}$ / $-\frac{2545\, HP_{REF}}{3600\, w_a h_b}$	$\overbrace{C_{T_1}'\left(1+\frac{\Delta w_a}{w_a}\right)}$ / $\frac{c_p T_{am}}{h_b}\left[1+\frac{\Delta w_a}{w_a}\right]$	$\overbrace{-1+C_{T_2}'\left(1+\frac{\Delta w_a}{w_a}\right)}$ / -1	
$\frac{\Delta F_n}{F_n}$ *	$\overbrace{1+C_d}$ / $1+\frac{F_g R T_{t7}'}{F_n 2 J h_n'}$	$\overbrace{C_d}$ / $\frac{F_g}{F_n 2 h_n'}\left(\frac{R T_{t7}'}{J}-C\right)$	$\overbrace{C_{bl}}$ / $\frac{F_g}{F_n}\left\{1+\frac{R T_{t7}'}{2 J h_n'}+\frac{1}{2 h_n'}\left[h_t-\frac{R T_{t3}}{J\eta_c}\right]\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta}{\eta}\right)+\frac{C}{c_p T_{t5}}\left(\frac{1}{2}-\frac{k}{k-1\eta_t}\right)\right]\right\}$	$\overbrace{C_{px}}$ / $\frac{F_g 2545\, HP_{REF}}{F_n 3600\, w_a 2 h_n'}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)+\frac{C}{c_p T_{t5}}\left(\frac{1}{2}-\frac{k}{k-1\eta_t}\right)\right]$	$\overbrace{C_{T_1}}$ / $\frac{F_g c_p T_{am}}{F_n 2\eta_c h_n'}\left[\frac{T_{t3}}{T_{am}}-1\right]\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)+\frac{C}{c_p T_{t5}}\left(\frac{1}{2}-\frac{k}{k-1\eta_t}\right)\right]$	$\overbrace{C_{T_2}}$ / $-1-\frac{F}{F_n 2 h_n'}\left\{\frac{R T_{t7}'}{J}-\frac{R T_{t3}}{J\eta_c}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)+\frac{C}{c_p T_{t5}}\left(\frac{1}{2}-\frac{k}{k-1\eta_t}\right)\right]\right\}$	CONSTANT EXHAUST NOZZLE AREA $\frac{\Delta A}{A}=0$
$\frac{\Delta w_f}{w_f}$ *	$\overbrace{1}$ / 1	$\overbrace{C_d'}$ / $-\frac{D}{h_b}$	$\overbrace{1+C_{bl}'\left(1+\frac{w_{bl}}{w_a}\right)}$ / $1+\frac{1}{h_b}\left[\frac{R T_{t3}}{J\eta_c}+\frac{D}{c_p T_{t5}}\left(h_t-\frac{R T_{t3}}{J\eta_c}\right)\left(\frac{1}{2}-\frac{k}{k-1\eta_t}\right)\right]\left[1+\frac{w_{bl}}{w_a}\right]$	$\overbrace{C_{px}'}$ / $\frac{2545\, HP_{REF}\, D}{3600 w_a c_p T_{t5} h_b}\left(\frac{1}{2}-\frac{k}{k-1\eta_t}\right)$	$\overbrace{C_{T_1}'\left(1+\frac{\Delta w_a}{w_a}\right)}$ / $\frac{c_p T_{am}}{\eta_c h_b}\left(\eta_c+\left[\frac{T_{t3}}{T_{am}}-1\right]\left[1+\frac{D}{c_p T_{t5}}\left(\frac{1}{2}-\frac{k}{k-1\eta_t}\right)\right]\right)\left[1+\frac{\Delta w_a}{w_a}\right]$	$\overbrace{-1+C_{T_2}'\left(1+\frac{\Delta w_a}{w_a}\right)}$ / $-1+\frac{R T_{t3}}{J\eta_c h_b}\left[1+\frac{D}{c_p T_{t5}}\left(\frac{1}{2}-\frac{k}{k-1\eta_t}\right)\right]\left[1+\frac{\Delta w_a}{w_a}\right]$	

$$B=1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)-\frac{1-\frac{T_{t7}'}{2 T_{t4}}\left(\frac{k+1}{k}\right)-\frac{(k-1)T_{t3}}{2k\eta_c T_{t4}}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]}{1-\frac{(k-1)T_{t3}}{2k\eta_c T_{t4}}}$$

$$C=\frac{c_p T_{t4}-\frac{R T_{t7}'}{2J}\left(\frac{k+1}{k-1}\right)-\frac{R T_{t3}}{2J\eta_c}\left[1+\frac{T_{t7}'}{T_{t5}}\left(\frac{1-\eta_t}{\eta_t}\right)\right]}{\left[\frac{T_{t4}}{T_{t5}}-1\right]\frac{k+1}{2(k-1)}+\frac{(k-1)T_{t3}}{2k\eta_c T_{t5}}\left[\frac{1}{2}-\frac{k}{k-1\eta_t}\right]}$$

$$D=\frac{c_p T_{t5}-\frac{R T_{t3}}{2J\eta_c}}{\left[\frac{T_{t4}}{T_{t5}}-1\right]\frac{k+1}{2(k-1)}+\frac{(k-1)T_{t3}}{2k\eta_c T_{t5}}\left[\frac{1}{2}-\frac{k}{k-1\eta_t}\right]}$$

* THE SIGNS OF THE COEFFICIENTS HAVE BEEN CHANGED SO THAT A DECREASE OF THESE QUANTITIES IS POSITIVE

FIG. 19 EXPRESSIONS FOR CORRECTION FACTORS FOR THREE TYPICAL ENGINE CONTROLS

to the losses, an acceptable accuracy resulted, as is shown in the discussion.

Discussion

(1) The altitude curves similar to Fig. 1, being dimensional curves, are intelligible to those not versed in δ and θ corrected quantities. It is also possible to allow for changes in combustion, compressor and turbine efficiencies, and specific heats with altitude and flight speed.

(2) The engine operating limits (flight speed, rotational speed, altitude, and idling speed) are easily indicated on the dimensional curves, Fig. 1, whereas it is difficult to indicate actual operating limits on corrected curves employing δ and θ.

(3) Only the regions of the performance curves which are of interest to the airplane designer need be corrected by him for duct losses, air bleeding, etc. For instance, the curves need only be corrected in the region where the airplane drag polar intersects the engine thrust curves in order to establish the maximum flight speed. Similarly, for range problems, the curves need only be corrected in the region where the drag polar is tangent to the pound-per-mile curves. This should considerably reduce the airplane calculation work.

(4) The actual engine airflow is not given on Fig. 1. The corrected airflow is given on Fig. 6, because the corrected flow is more useful in combining the engine and inlet duct characteristics. If actual airflow were given, the airplane designer would have to calculate the total pressure and temperature if he is to obtain the Mach Number at the duct outlet (compressor inlet).

For example, the loss in any inlet duct can be given as

$$\Delta p_{t2}/p_{t2} = \text{a function of } (M_1, M_2)$$

where

Δp_{t2} = the inlet duct loss in total pressure
p_{t2} = compressor inlet total pressure
M_1 = flight Mach Number
M_2 = compressor inlet (duct exit) Mach Number

Since M_2 is simply related to the engine corrected flow (as shown below), it is more convenient to use the corrected flow for the duct performance.

$$\Delta p_{t2}/p_{t2} = \text{a function of } (M_1, \Gamma_{t2})$$

Table 1

Assumed Change	Ratio of Correction Factor Thrust to Cycle Thrust	Ratio of Correction Factor Fuel Flow to Cycle Fuel
Duct loss, $\Delta p_{t2}/p_{t2} = 20\%$	0.982	1.000
Power extraction, (hp.$_{ext.}$/hp.$_{ref.}$) = 20% (150 hp. for 4,000-lb. thrust)	1.000	1.000
Air bleed ($w_{bl.}/w_a$) = 10%	0.991	1.008
Ambient temperature, $\Delta T_{am.}/T_{am.}$ = −24% (+59° to −67°F.)	1.017	1.000

where

$$\Gamma_{t2} = \frac{w_a(\sqrt{\theta_{t2}})}{\delta_{t2}} \frac{1}{A_2 P_0} \sqrt{\frac{RT_0}{g}} = \frac{M_2}{\left(\frac{k-1}{k} M_2^2 + 1\right)^{(k+1)/2(k-1)}}$$

(5) The correction factors (C_d, $C_{bl.}$, etc.) can be calculated by the engine builder from the no-loss performance data used to construct the performance curves of Fig. 1. Thus, it is unnecessary to carry out additional cycle calculations with the various losses included.

(6) The correction factor curves show the relative importance of the losses and their variation with flight conditions. For instance, $(1 + C_d)$ is the per cent loss in thrust per per cent loss in inlet total pressure, and $C_{bl.}$ is the per cent loss in thrust due to 1 per cent air bleed. The values of the correction factors for older engines can also serve as approximations to those for new engines in cases where data on the new engine are lacking.

(7) Some idea of the accuracy of the correction factor method can be obtained from Table 1, which gives the ratios of the thrusts and fuel flows obtained by (a) correcting the no-loss cycle results and (b) by an independent cycle calculation in which the particular loss is assumed. It should be noted that the assumed losses are the extreme values to be expected in practice.

(8) The correction factors can be calculated using the expressions on Fig. 19 or can be obtained as a result of engine tests.

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I.A.S. Previews

Summaries of Current Papers Accepted for I.A.S. Publications

The Minimum Drag of Thin Wings in Frictionless Flow

By

Robert T. Jones

Ames Aeronautical Laboratory, N.A.C.A.

The assumptions of the thin airfoil theory are found to provide certain necessary conditions for the minimum drag of airfoils having a given total lift, a given maximum thickness, or a given volume. The conditions are applicable to steady or unsteady motions and to subsonic or supersonic speeds without restriction on the plan form. The computation of drag and the statement of the conditions for minimum drag depend on the consideration of a "combined flow field," which is obtained by superimposing the disturbance velocities in forward and reversed motions.

If the plan form of the airfoil and its total lift are given, it is found that, for minimum drag, the lift must be distributed in such a way that the downwash in the combined field is constant over the entire plan form. If the plan form is given and the thickness of the airfoil is required to contain a specified volume, then the thickness must be distributed over the plan form in such a way that the pressure gradient of the combined field in the direction of flight is constant at all points of the wing. A specification of the thickness along some line drawn on the plan form is found to lead to the requirement that the gradient of the pressure vanishes on either side of this line. For the drag to be a minimum with respect to small changes in the plan form the foregoing conditions must extend continuously for a small distance beyond the edge of the plan form.

Preprint No. 289

Nonstationary Motion of Purely Supersonic Wings

By

Jack E. Froehlich

California Institute of Technology

A general theory is presented for the calculation of the total forces acting on purely supersonic wings. The method applies to wings having an arbitrary downwash distribution (stationary or nonstationary) and is valid whenever all of the wing edges are supersonic. The general three-dimensional nonstationary problem is reduced to an equivalent two-dimensional problem. In the case of harmonic oscillations, the aerodynamic coefficients are expressed in terms of known or tabulated functions. The specific example of an oscillating delta wing is considered, and values of the aerodynamic coefficients for plunging, pitching, and rolling oscillations are calculated for two Mach Numbers.

First- and Second-Order Theory of Supersonic Flow Past Bodies of Revolution

By

Milton D. Van Dyke

The RAND Corporation and California Institute of Technology

Methods are studied for improving the existing perturbation theories of supersonic flow past bodies of revolution. Applicability of the theory at high Mach Numbers is emphasized.

For axial flow, a second-order solution is found which represents a considerable improvement over the first-order result. For inclined flow, a second-order solution is not feasible except for a cone. Comparison with the exact solutions for cones shows that the slender-body series expansion causes large inaccuracies in both axial and inclined flow.

The conclusion that first-order theory predicts the flow no better than slender-body theory is shown to be erroneous. When first-order theory is properly used, making no unnecessary approximations, greatly improved agreement is found with exact solutions and with experiment. The order estimates used to justify the approximations are shown to be invalid in most practical cases. A "hybrid" theory, combining first-order cross flow and second-order axial flow, gives further improvement. A physical explanation is advanced for the marked superiority of first-order theory over the true "linearized" theory.

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Nonlinearity in lift is shown to result primarily from viscous separation of the cross flow along the after portions of a long body. The magnitude of the resulting normal force can be estimated with reasonable accuracy using two-dimensional viscous sweepback theory.

Calculation of Thermal Stresses in a Wedge-Shaped Wing

By

George H. Eisenhardt and Warren M. Rohsenow

Massachusetts Institute of Technology

A method for calculating thermal stresses is presented and applied to a solid symmetrical double-wedge steel wing flying at an altitude of 50,000 ft. The wing, after flying steadily at a Mach Number of 1.4 and having a uniform temperature distribution of 531.6°F. absolute, is accelerated at a constant rate of one Mach Number per 30 sec. until a Mach Number of 6.0 is reached. Thermal stresses at the instant the wing reaches a Mach Number of 6.0 are calculated using the elastic properties of steel at room temperature. An interpolation method is presented for estimating the thermal stress during the acceleration.

The Interaction of Shock Waves with Boundary Layers on a Flat Surface

By

F. W. Barry, A. H. Shapiro, and E. P. Neumann

Massachusetts Institute of Technology

The development of supersonic compressors, supersonic diffusers, and high-speed aircraft points to the increasing importance of the interaction between shock waves and boundary layers.

The experimental work reported here is intended to (1) provide a better understanding of the nature of the shock-boundary-layer interaction, (2) serve as a guide and stimulus to theoretical work, and (3) develop an empirical method for predicting the effects of the interaction.

Experiments were performed on the reflection of an oblique shock from a boundary layer on a flat surface at a Mach Number of 2.05. The effects of shock strength and boundary-layer régime (laminar, transition, or turbulent) on the interaction phenomena were explored.

The results are in the form of schlieren photographs, constant-density contours found from interferometer photographs, and static pressure distributions at the plate surface.

The Performance of Axial-Flow Compressors As Affected by Single-Stage Characteristics

By

Seymour M. Bogdonoff

Princeton University

A series of calculations were carried out to obtain the performance of a six-, an eight-, and a 13-stage compressor, each designed for the same tip speed, to handle the same mass flow, and to develop a pressure ratio of 3.2. The simplified analysis was based on experimental cascade and single-stage studies. The effects of boundary-layer growth and distortion of the velocity profiles, which occur at the rear of multistage axial-flow compressors, were neglected. The conclusions were as follows:

(1) The compressor with the fewest stages (highest loaded stages) has the widest mass flow range. The six-stage compressor has a range of mass flow of 41 per cent of design mass flow; the eight-stage, 28 per cent; and the 13-stage, only 14 per cent.

(2) The compressor with the fewest stages has the flattest pressure ratio and efficiency variation with mass flow. The more numerous the stages, the steeper the characteristics—i.e., the greater the pressure ratio range.

(3) The flat characteristics are due primarily to the fact that, for a given change in mass flow, the percentage change in developed pressure ratio or axial velocity is smallest for highly loaded blades.

(4) The calculations show that, for most configurations, stalling of a multistage compressor occurs throughout the compressor at the same instant; this is in contradiction to the usual belief that stalling occurs first at the rear and progresses forward.

(5) A method is suggested for forcing the compressor to stall at the rear first. This may be a way to eliminate the sudden sharp stall usually associated with multistage compressors.

Supersonic Wing-Body Lift

By

George Morikawa

Hughes Aircraft Company

The representation of lift for a fairly general family of wing-body configurations (with no afterbody) in a linearized supersonic flow is considered over the entire range of the parameters. The bracketing limits of lift are obtained simply using the most elementary considerations when the interpretation of these limits is recognized. By the proper choice of the independent parameters and the proper representation of the lift, reasonable approximations for the behavior of lift for intermediate values of the parameters are obtained.

Further generalization to other wing plan forms with straight edges and other body shapes and the representation of other aerodynamic variables such as drag, moment, and center of pressure will be evident but not considered in detail.

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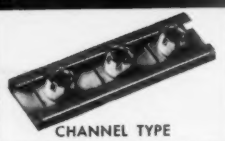

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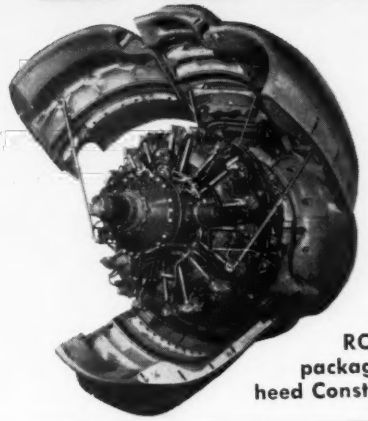

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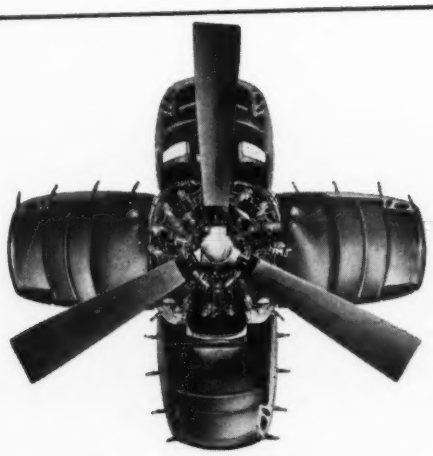

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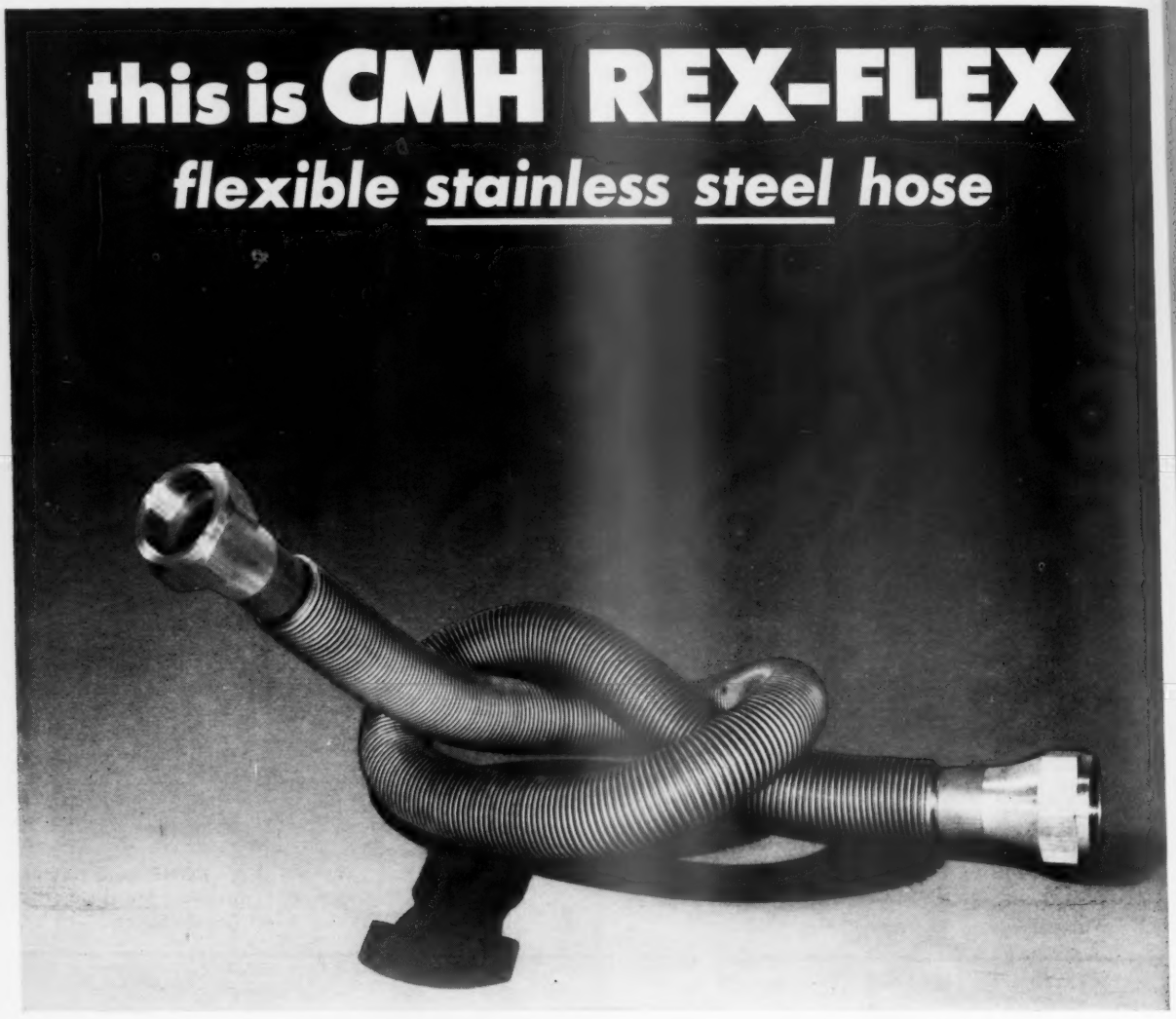

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Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

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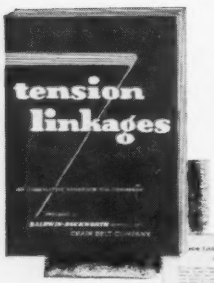

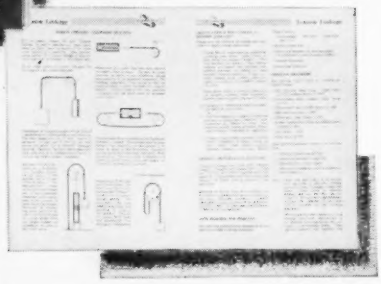

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Aerodynamics (2)

BOUNDARY LAYER

The Laminar Boundary Layer on Solids of Revolution. L. G. Whitehead and G. S. Canetti. *Philosophical Magazine*, Vol. 41 (7th Series), No. 321, October, 1950, pp. 988–1000, illus. 9 references.

Derivation of boundary-layer equations. Solutions for the flow past cones is related to the corresponding two-dimensional flows past wedges. A velocity distribution that involves three terms is used; it gives satisfactory results for all of the accelerated portion of the boundary layer of slender bodies, and for the earlier portion of retarded flow. At practical Reynolds Numbers, the transition to turbulence will usually occur before the solution using three terms ceases to apply. This method is applicable to the whole of the boundary layer up to the separation point (where a solution employing four terms must be used). Calculation of the boundary-layer flow on an ellipsoid of fineness ratio of 3 gives satisfactory results over the forward 80 per cent of the laminar layer, but no solution is obtained close to the laminar separation point.

Wind Tunnel Measurements on a Four-Motored Complete Model with and Without Boundary Layer Control. W. Krüger. (*Göttingen, Aerodynamische Versuchsanstalt, ZWB/FB/1793*, April 8, 1943.) *Cornell Aeronautical Laboratory, Inc., Translation*, March, 1950. 67 pp., illus. 10 references.

A method of producing high lift; air is taken by suction into the rectangular center section of the wing and blown out over the aileron. The lift coefficients obtained with this type of wing are much higher than those of wings with normal high-lift devices. The firm of Junkers was the first to develop a multiengined airplane using boundary-layer control for increased lift. Results are given of three- and six-component tests on the complete model and the model without tail surfaces, as well as measurements with and without boundary-layer control and with and without power. Further measurements with an additional slot were made in the wing region influenced by the nacelles. The power requirements for the full-scale assembly were estimated; a considerable power increment is needed if high force-coefficient values are to be attained at greater wing loading.

Interaction Between the Laminar Boundary Layer over a Plane Surface and an Incident Oblique Shock Wave. Lester Lees. *Princeton University, Aeronautical Engineering Laboratory, Report No. 143*, January 24, 1949. 60 pp., illus. 10 references.

Away from the shock wave, the boundary-layer theory remains valid. The boundary layer separates upstream of the shock. Pressure rise upstream of the shock through the subsonic portion of the boundary layer decays exponentially with distance from the shock. The relaxation distance varies with Reynolds Number; it is greatest near $M = 1.0$. For the incident shock, the relaxation distance is greatest near $M = 1.15$. As Reynolds Number decreases, the separation point moves closer to the incident shock wave. This study gives only approximate solutions to the boundary-layer-shock-wave interaction problem.

Boundary-Layer Measurements in a 3.84- by 10-Inch Supersonic Channel. Paul F. Brinich. *U.S., N.A.C.A., Technical Note No. 2203*, October, 1950. 51 pp., illus. 10 references.

On the Frictional Coefficient of a Flat Plate with Partly Laminar and Partly Turbulent Boundary Layer. Ryuichiro Matsufuji. *Japan Society for Applied Mechanics, Journal*, Vol. 3, No. 17, May, 1950, pp. 110–114, illus. 4 references. In English.

Derivation of a formula for the coefficient of friction assuming (1) that the displacement thickness of the laminar boundary layer ahead of the transition point is equal to the displacement thickness behind the transition point, and (2) that if the turbulence flow begins at the transition point, the phenomena behind the point are independent of the phenomena ahead of the point. For the purposes of comparison, an approximate formula of the same form as Prandtl's is derived. The values of C_f which are calculated by the exact method are in good agreement with those obtained from the approximate formula, but both sets of values are slightly higher than those obtained from Prandtl's solution.

CONTROL SURFACES

The Oscillating Rectangular Control Surface at Supersonic Speeds. John W. Miles. *U.S., Naval Ordnance Test Station, Inyokern, Calif., NAVORD Report No. 1185 (NOTS 241)*, October 4, 1949. 13 pp., illus. 7 references.

Calculation of the force and moments on an oscillating rectangular control surface mounted on a rectangular wing, with the assumption that the outboard end of the control surface is coincident with the side edge of the wing. The pressure distribution is calculated in the region of the control-surface adjacent to the surface at zero angle of attack. This pressure distribution cannot be expressed as finite terms of known functions, but certain integrals of the pressure can be obtained over spanwise strips. The force and moments on the spanwise strips are applied to a determination of the force and moments on a wing of finite aspect ratio with the restriction that the Mach lines from the leading edge corners do not intersect ahead of the trailing edge. The procedure is extended to wings of lower aspect ratio. The loss of lift on the control surface due to the presence of the inboard edge is $2/\pi$ times that due to an outboard edge.

Wind-Tunnel Investigation at Low Speed of the Lateral Control Characteristics of an Unswept Untapered Semispan Wing of Aspect Ratio 3.13 Equipped with Various 25-Percent-Chord Plain Ailerons. Harold S. Johnson and John R. Hagerman. *U.S., N.A.C.A., Technical Note No. 2199*, October, 1950. 32 pp., illus. 17 references.

Theoretical Supersonic Characteristics of Inboard Trailing-Edge Flaps Having Arbitrary Sweep and Taper: Mach Lines Behind Flap Leading and Trailing Edges. Julian H. Kainer and Jack E. Marte. *U.S., N.A.C.A., Technical Note No. 2205*, October, 1950. 39 pp., illus. 6 references.

FLUID MECHANICS & AERODYNAMIC THEORY

Stability of Viscous Flow over Concave Cylindrical Surfaces. D. Meksyn. *Royal Society (London), Proceedings, Series A, Mathematical and Physical Sciences*, Vol. 203, No. 1073, September 22, 1950, pp. 253–265. 6 references.

Investigation of the stability of three-dimensional disturbances by the method of asymptotic solutions. The derivation of the equations of disturbed motion is followed by the solution of the asymptotic integrals. The asymptotic integrals depend chiefly on the integral properties of the velocity curve. Since the asymptotic integrals are not valid in the edge of the boundary layers, the required boundary conditions are provided by integrating the equations for the velocity parameter U = constant. This study confirms Görtler's conclusions that the disturbances can take place only on concave surfaces. The existence of many steady states is proven. This simplified general solution agrees completely with the theoretical and experimental results obtained by Taylor for the rotating cylinder.

An Experimental Investigation of Transonic and Accelerated Supersonic Flow by the Hydraulic Analogy. E. V. Laitone. *California, University, Department of Engineering, Fluid Mechanics Laboratory, Report No. HE-116-315, Series 3, Issue 315*, July 3, 1950. 20 pp., illus. 12 references.

The transonic problems of detached shock waves in front of a simple wedge moving at varying supersonic speeds. The analogy between surface water waves and two-dimensional potential gas flow is reviewed. A rectangular tank, 4- by 20 ft., with a water depth of approximately 0.35 in., was used, and the models were towed by a carriage mounted on rails. The models were simple wedge noses with rectangular afterbodies and had wedge angles of 10°, 20°, 30°, and 40°. Photographs of the models show shock-wave patterns in the water.

The Formation of Vortex Sheets in a Simplified Type of Turbulent Motion. J. M. Burgers. (*Delft, Technische Hogeschool, Laboratorium voor Aero- en Hydrodinamica, Mededeling No. 64.*) *K. Nederlandsche Akademie van Wetenschappen, Proceedings*, Vol. 53, No. 2, 1950, pp. 122–133, illus. 5 references. In English. Reprint.

Mathematical development of any field in which the initial state is formed by a patchwork of homogeneous domains with rectilinear boundaries between them. By distinguishing between contracting and diverging domains and following the movement of the contracting segments, it is found that all domains contract into segments that are lines of sinks and concentrated vorticity. Neighboring lines may approach each other and unite. This results in a gradual increase of the cross dimensions of the remaining domains with divergent motion. It is expected that the thickness of the vortex sheet will increase, but at a different rate from the increase of the cross dimensions of the domains. This development gives a basis for the statistical study of turbulence in which the vorticity is concentrated in vortex sheets.

The Fully Developed Turbulent Wake of a Circular Cylinder. A. A. Townsend. *Australian Journal of Research, Series A, Physical Sciences*, Vol. 2, No. 4, December, 1949, pp. 451–468, illus. 14 references.

Experimental investigation in the 15- by 15-in. wind tunnel at Cavendish Laboratory, Cambridge, of a fully turbulent wake of a cylinder 0.159-cm. in diameter in an air-stream velocity of 1,280 cm. per sec. The fully turbulent core of the wake emits slow jets of fully turbulent fluid. These jets, as a result of their motion away from the center of the wake, transmit turbulent energy and heat at a rate depending upon the local intensity and outward velocity of the jet. Measurements at a distance of 500–950 diameters downstream from the cylinder gave further indication that jet convection is not solely responsible for the turbulent flow and that the effect of ordinary diffusion is appreciable.

Diffusion in a Field of Homogeneous Turbulence. I—Eulerian Analysis. G. K. Batchelor. *Australian Journal of Scientific Research, Series A, Physical Sciences*, Vol. 2, No. 4, December, 1949, pp. 437–450, illus. 15 references.

Mechanism of diffusion from a fixed center in a homogeneous field of turbulence. If the statistical behavior of a single fluid particle is known, the diffusion of a cloud of marked fluid particles about the average position of their center is known. An Eulerian type of analysis which is concerned with the probability of finding marked fluid at a given point of space at a given time is used. Equations are derived for the dispersion of a single fluid particle, and for the probability distribution of the displacement components. The diffusion is represented by a differential equation of the heat-conduction type; the diffusion coefficient at first increases with time and then becomes constant.

The Decay of Axisymmetric Turbulence. S. Chandrasekhar. *Royal Society (London), Proceedings, Series A, Mathematical and Physical Sciences*, Vol. 203, No. 1074, October 10, 1950, pp. 358–364. 10 references.

Explicit solutions, appropriate for the final period of decay, are obtained; these solutions are in agreement with Batchelor's general results on the role of big eddies in homogeneous turbulence. It is shown that, compatible with the equations that have been derived for axisymmetric turbulence, a state of turbulence exists which may be pictured as a superposition of two non-interacting fields that are isotropic and axisymmetric, respectively.

Correlation Problems in a One-Dimensional Model of Turbulence. I–IV. J. M. Burgers. (*Delft, Technische Hogeschool, Laboratorium voor Aero- en Hydrodinamica, Mededeling Nos. 65a–65d.*) *K. Nederlandsche Akademie van Wetenschappen, Proceedings*, Vol. 53, Nos. 3, 4, 6, 1950, pp. 247–260; 393–406; 718–742; illus. 10 references. In English. Reprint.

Investigation of the correlation in approximate solutions of $(\partial v/\partial t) + v\,(\partial v/\partial y) = \nu\,(\partial^2 v/\partial y^2)$ considering ν to be extremely small. An important property of this approximate solution is that the members can be measured and counted, thus providing for a statistical analysis. Expressions are constructed for the correlation functions, which contain several series of other mean values giving the dimensions of the domains. Substituting the expressions obtained for the correlation functions into the fundamental equation for the propagation of correlation gave a number of relations between the mean values. When this equation is supplanted by the hypothesis that the correlation function is of the self-preserving type, no method is found which would give the value of these quantities. In attempting to show whether a tendency exists toward the development of self-preserving correlation functions, one set of factors describing the domain were assumed to retain a certain value throughout the system. A consideration of the equations of motion leads to the derivation of a Boltzmann equation for the distribution functions for these factors. This method, although serving as a mathematical model for the study of turbulent flows, poses many questions for further study.

On the Derivation of Euler's Equation for the Motion of an Inviscid Fluid. S. Corrsin. *American Journal of Physics*, Vol. 18, No. 7, October, 1950, p. 467. 3 references.

Note on the Damping of the Rotational Oscillation of a Spherical Mass of an Elastic Fluid in Consequence of Slipping Along the Boundary. J. M. Burgers. (*Delft, Technische Hogeschool, Laboratorium voor Aero- en Hydrodinamica, Mededeling No. 60.*) *K. Nederlandsche Akademie van Wetenschappen, Proceedings*, Vol. 52, No. 2, 1949, pp. 113–119, illus. 5 references. In English. Reprint.

Mathematical Formulation of Bodies of Revolution. L. Landweber and M. Gertler. *U.S., Navy Department, David W. Taylor Model Basin, Report No. 719*, September, 1950. 64 pp., illus. 6 references.

The most satisfactory method of obtaining a body of revolution is one that defines the sectional-area curve by means of a polynomial. The degree of the polynomial fixes the number of parameters which may be prescribed to determine a form. Formulas for generating sixth-degree polynomial forms are derived. The expression for the sectional-area curve is a linear combination for the nose and tail radii and the prismatic coefficient, with polynomials of the sixth-degree as coefficients. These coefficients are given in formulas and tables. Not all combinations of parameters give usable forms; standards are formulated for determining the range of usable forms. Formulas for seventh-degree polynomial forms are derived and compared with sixth-degree forms for the same range of basic values. Bodies of revolution derived from polynomials of other than the sixth-degree may be fitted to the sixth-degree forms by the method of least squares.

Transonic Flow Past Wedge Sections. H. W. Liepmann and A. E. Bryson, Jr. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, pp. 745–755, illus. 13 references.

Some Recent Investigations in the Theory of Hydrodynamic Stability. J. R. Foote and C. C. Lin. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 265–280, illus. 9 references.

Investigation of the effects of viscosity on unsymmetric two-dimensional flows in jet and wakes. An extension of Wasow's method of asymptotic solutions shows that the "viscous solutions" must be rejected for these flows and that the effect of viscosity must be determined from the second-order approximation of the inviscid solutions. The inviscid approximations are examined with special reference to the stability of jets and wakes. In all cases, the occurrence of the maximum or minimum of vorticity is necessary for the existence of nontrivial neutral and self-excited disturbances in the flow. For unsymmetric velocity distributions, the neutral disturbance may give rise to a Reynolds shear stress that is opposite in sign to the velocity gradient of the mean flow. These ordered oscillations differ from fully developed turbulent flow in that they can transfer momentum from a region of lower mean velocity to a region of higher mean velocity.

Effect of Heat-Capacity Lag on the Flow Through Oblique Shock Waves. H. Reese Ivey and Charles W. Cline. *U.S., N.A.C.A., Technical Note No. 2196*, October, 1950. 28 pp., illus. 5 references.

An Extension of the Theory of the One-Dimensional Shock-Wave Structure. Leonard Meyerhoff. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, pp. 775–786, illus. 16 references.

Readers' Forum: An Analogy Between Open Soap Bubble and Compressible Flow. V. G. Szebehely. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, p. 809.

INTERNAL FLOW

Analysis of the Air Flow Through Four Stages of Half-Vortex Blading in an Axial Compressor. D. G. Ainley and R. A. Jeffs. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2383*, 1950 (April, 1946). 27 pp., illus. 8 references. British Information Services, New York. $1.25.

Results of Mach Number tests show a steady deterioration of the radial distribution of the axial velocity through the compressor. The air deflections in each blade row agreed well with values obtained in cascade tests but were considerably different from the computed design values. There was evidence of a pair of trailing vortices on each blade and of the formation of secondary induced flows. A change in axial velocity distribution through the compressor should reduce stalling losses at the blade tips and roots in the high-pressure stages.

The Flow Through Centrifugal Compressors and Pumps. H. E. Sheets. *American Society of Mechanical Engineers, Transactions*, Vol. 72, No. 7, October, 1950, pp. 1009–1015, illus. 13 references.

An exact solution is not obtainable for the three-dimensional flow problem. An approximate solution can be found for the differential equations of flow through an impeller if specific assumptions are made and if the speed is held within certain limits. Equations are derived for the velocity by considering the center section of the impeller-blade passage as a rotating channel. An approximate velocity and pressure distribution can be calculated for the entire impeller passage. An analysis of the velocity distribution gives some information on pulsation and stalling phenomena. For the theoretical two-dimensional case, this method is compared with the relaxation method of Emmons. Results agree with those of Emmons for the backward-curved impeller; for the radial-vaned impeller, the results are somewhat higher than Emmons' results. This analysis is applicable to mixed-flow compressors and to radial and mixed-flow turbines.

Two-Dimensional Compressible Flow in Centrifugal Compressors with Straight Blades. John D. Stanitz and Gaylord O. Ellis. *U.S., N.A.C.A., Report No. 954*, 1950. 23 pp., illus. U.S. Govt. Printing Office, Washington. $0.25.

The Incompressible Flow About Thin Airfoils in a Cascade of Small Solidity. Henry W. Woolard. *Cornell Aeronautical Laboratory, Inc., Report No. 29*, September, 1949. 17 pp., illus. 7 references.

A simple theory for calculating the lift coefficient, lift-curve slope, quarter-chord pitching-moment coefficient, and surface-pressure coefficients for a cascade of thin airfoils having a low solidity value (considerably less than unity). The expressions derived require a knowledge of the isolated airfoil coefficients at the same angle of attack. Comparison with the results for a flat plate (calculated by the exact method of Weinig) indicates that the maximum error with increase in solidity occurs for blade angles of approximately 40°, with the error decreasing as the blade angle changes from 40°. The error is minimum at a blade angle of approximately $40° \pm 20°$; for larger increments the error reverses sign. Application of these expressions should be restricted to solidities of less than 0.55. However, some higher solidity values are permissible, depending on the blade angle. This method is said to be more concise and easier to apply than others.

Tests in the N.P.L. Electric Tank on a 4:1 Axi-Symmetrical Diffuser Having a Discontinuity in the Wall Velocity. F. Cheers and W. G. Rayner. *Gt. Brit., Aeronautical Research Council, Current Papers No. 2*, 1950 (March 26, 1946). 6 pp., illus. 2 references. British Information Services, New York. $0.25.

Tests to design a diffuser having a single velocity discontinuity at the wall, and with constant wall velocity up- and downstream. Modifications were made on a shape having a steep velocity gradient over a short length of the wall in order to steepen the velocity discontinuity; accurate control was extremely difficult in the region of the discontinuity. In the final shape, the velocity distribution is extremely flat, with a sharp change over a short length of the wall. Test results are tabulated, and the final design shape is shown.

An Investigation of Ejector Design by Analysis and Experiment. J. H. Kennan, E. P. Neumann, and F. Lustwerk. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 299–309, illus. 6 references.

A one-dimensional analysis of jet pumps or ejectors. Primary and secondary streams are mixed at constant pressure and at constant area. Mixing of the streams is always complete in the constant-area region. Transverse shock may occur between the regions of constant pressure and constant area. The tests showed that better performance is obtained with constant-pressure mixing. Experimental and analytical results agree over a wide range of variables. Experimental results for the mixing length in which the primary stream accelerates the secondary stream shows that the length needed depends on both the mixing process and the shock process. The method is applied to the proper design of an efficient jet pump.

Readers' Forum: Note on Desirability of Completely Expanded Nozzles. C. B. Cohen and P. J. Evans, Jr. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, pp. 811, 812, illus. 1 reference.

Research Trends: The Supersonic Compressor. Robert McLarren. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 50, 52, 54, 106–108, illus. 9 references. History, theory, and application.

Readers' Forum: The Reflection of "Rectilinear" Waves in One-Dimensional Gas Flows. Lorenzo Poggi. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, pp. 813–815, illus. 3 references.

Theoretical Investigation and Application of Transonic Similarity Law for Two Dimensional Flow. W. Perl and Milton M. Klein. *U.S., N.A.C.A., Technical Note No. 2191*, October, 1950. 42 pp., illus. 14 references.

NATURAL FLIGHT

Performance Measurements of a Soaring Bird. August Raspet. *Aeronautical Engineering Review*, Vol. 9, No. 12, pp. 14–17, illus. 1 reference.

PARASITIC COMPONENTS & INTERFERENCE

Drag Measurements on a Wing with a Fastened Bomb SC 50. Helmut Heinrich and Gerhard Ritschel. (*Forschungsanstalt Graf Zeppelin, Stuttgart-Ruit, Bericht Nr. 233*, October 30, 1942.) *Cornell Aeronautical Laboratory, Inc., Translation*, August, 1949. 182 pp., illus.

Wind-tunnel measurements of the drag increase of a N.A.C.A. 2412 wing with attached ETG 50 bomb suspension rack and a SC 50 bomb attached. The drag of the wing-bomb configuration is greater than the sum of the individual drags of the wing and the bomb (with rack). A description of the test setup and procedure is included. Twenty-three different rack suspensions were tested, and a rack apparatus that decreases the drag about 30 per cent was designed. The drag increase was determined by comparing the polars of the wing alone with the polars of the wing-bomb configuration. The drag increase was calculated for the wing with two SC 50 bombs attached. The results of the wind-tunnel tests and calculations are tabulated. Sketches show the rack designs tested.

Drag of a Wing Carrying an SC 1000 Bomb with and Without Faired-In Tail Surfaces. Scholkemeier. (*Brunswick, Luftfahrtforschungsanstalt Hermann Göring, Institut für Aerodynamik, Untersuchungen und Mitteilingen Nr. 2140*, December 9, 1944.) *Cornell Aeronautical Laboratory, Inc., Translation*, July, 1949. 7 pp., illus.

Wind-tunnel measurements on the drag of an SC 1000 bomb suspended from a wing. The drag of the wing-plus-faired bomb was slightly larger than the C_D of the wing alone; the drag of the wing-plus-unfaired bomb was much greater than that of the wing alone. The change in lift per angle of attack decreased for all faired bomb arrangements. Measurements are given in tabular and graphical form.

The Influence of the Induced Sidewind on the Efficiency of the Vertical Tail; A Simplified Method for Calculation. Willi Jacobs. *Sweden, Flygtekniska Försöksanstalt, Stockholm, Meddelande Nr. 35*, 1950. 31 pp., illus. 10 references. Kr. 3:50. In English.

The method is based on a vortex system according to the Prandtl wing theory, which consists of the supporting vortex at the place of the wing and a free vortex sheet lying in the x-y plane. The induced antisymmetrical lift distribution in yaw is approximated by three polynomials with three free constants. Tables and graphs give the influence functions of the single polynomials on the induced side wind. The method is applied to the calculation of the induced side wind on special wing-fuselage combinations. Results agree with those obtained by previous methods.

Influence of a Wing by Attached Loads. (*Stuttgart, Technische Hochschule, Flugtechnisches Institut, Bericht Nr. 104*, July 3, 1940.) *Cornell Aeronautical Laboratory, Inc., Translation*, September, 1949. 57 pp., illus.

Wind-tunnel investigation of the change in profile characteristics of various bomb and bomb-rack arrangements attached to a rectangular wing with end plates. Suitable fairings for the bomb rack kept the drag increase at a minimum. The drag increase is large because of the interaction of the wing and attached load and the stagnation area behind the load. The outboard rack of bombs decreased the maximum lift approximately 6 to 8 per cent. The diving moment decreased as the attached load increased. Results of the wind-tunnel tests are tabulated, and the drag increase is calculated for the case of a Ju 88 with two outboard-attached SC 500 bombs.

The Aerodynamic Forces on Slender Plane- and Cruciform-Wing and Body Combinations. John R. Spreiter. *U.S., N.A.C.A., Report No. 962*, 1950. 17 pp., illus. 19 references. U.S. Govt. Printing Office, Washington. $0.20.

Readers' Forum: Note on Base Pressure Measurements. Dean R. Chapman. *Journal of the Aeronautical Scientes*, Vol. 17, No. 12, December, 1950, pp. 812, 813, illus. 10 references.

Lift and Moment Changes Due to the Fuselage for a Yawed Aeroplane with Unswept and Swept Wings. Willi Jacobs. *Sweden, Flygtekniska Försöksanstalt, Stockholm, Meddelande Nr. 34*, 1950. 51 pp., illus. 19 references. Kr. 5:50. In English.

Calculation of the effect of the fuselage on the lift distribution, pitching moment, and rolling moment for a sweptback wing. Six-component and pressure measurements were made on a straight wing and on a wing with a sweep angle of 40° (both high-wing and mid-wing configurations). Test measurements agreed well with the calculations from theory.

PERFORMANCE

Safety in Performance Operating Rules. R. B. Maloy. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 507.* 18 pp., illus.

Study of C.A.B. and C.A.A. performance operating regulations for transport aircraft. The measured performance of an aircraft is adapted to the dimensions of its take-off area, the terrain enroute, and its landing area. These regulations are defined, and any changes in recent years due to airplane improvements are explained. The basis of these rules is the requirements for safe, dependable flight.

Readers' Forum: On the Speed of an Airplane in Steady Flight. Angelo Miele. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, pp. 808, 809. 5 references.

STABILITY & CONTROL

Readers' Forum: On the Equations of Longitudinal Stability. John W. Miles. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, pp. 815, 816. 4 references.

A Flight Investigation and Analysis of the Lateral-Oscillation Characteristics of an Airplane. Carl J. Stough and William M. Kauffman. *U.S., N.A.C.A., Technical Note No. 2195*, October, 1950. 33 pp., illus. 6 references.

Progress in Stall Research. Graham Campbell and Gifford Bull. *Aeronautical Engineering Review*, Vol. 9, No. 11, November, 1950, pp. 24–32, illus. 7 references.

Measurement of the Moments of Inertia of an Airplane by a Simplified Method. Howard L. Turner. *U.S., N.A.C.A., Technical Note No. 2201*, October, 1950. 49 pp., illus. 8 references.

Why Transonic Speeds Bring Airplane Trim Changes. Robert B. Liddell. *SAE Journal*, Vol. 58, No. 10, October, 1950, pp. 62–65, illus. (Excerpts from a paper: Some High-Speed Experience with Fighter-Type Airplanes.)

THERMOAERODYNAMICS

The Transient Temperature Distribution in a Wing Flying at Supersonic Speeds. Joseph Kaye. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, pp. 787–807, 816, illus. 19 references.

WINGS & AIRFOILS

Sweepback and Wing Taper. V. M. Falkner. *Aircraft Engineering*, Vol. 22, No. 260, October, 1950, pp. 296–300, illus. 5 references.

Calculation of the effect of sweepback on the lift, drag, and aerodynamic center of a wing with a taper ratio of 0.32, aspect ratio of 5.82, and a sweep varying from 20° sweepforward to 45° sweepback, measured on the quarter chord line. The aerodynamic characteristics are obtained by use of either an 84 or a 126 lattice of vortices for the computation of the downwash and the determination of the constants in the equation representing the vortex sheet. The results are presented in tables and graphs.

On Harmonic Motion of Wide Delta Airfoils at Supersonic Speeds. John W. Miles. *U.S., Naval Ordnance Test Station, Inyokern, Calif., Technical Memorandum No. RRB-36*, February 9, 1950. 54 pp., illus. 8 references.

Derivation of formulas for the forces and moments on an oscillating delta wing that is bounded by two supersonic leading edges and a straight trailing edge perpendicular to the free stream. The formulation of these forces is found to be only slightly more complex than the corresponding two-dimensional case. Equations are given for the lift and pitching moments due to plunging and pitching; the lift, pitching, and rolling moments due to control surface deflections; and the damping moment in roll. The possibility of negative damping in pitch is investigated, and a formula is derived for the axis locations where the negative damp-

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ing can occur. In the formulation of the control surface derivatives, the downwash on a wide delta wing is assumed to vanish identically over the port half of the wing, and the control surface area only is considered. Curves and tables give the numerical results for a range of Mach Numbers.

Aerodynamic Derivatives for an Oscillating Rectangular Airfoil at Supersonic Speeds. John W. Miles and Irven Naiman. *U.S., Naval Ordnance Test Station, Inyokern, Calif., Technical Memorandum No. RRB-32,* October 3, 1949. 40 pp., illus. 7 references.

Calculation of the flutter derivatives for a rectangular wing in longitudinal plane motion which has two symmetrically located control surfaces that do not interfere aerodynamically. The aerodynamic derivatives for the lift and moment of the wing are formulated in terms of corrections on the two-dimensional results. These corrections are calculated and plotted for a range of Mach Numbers. The hinge moment on the ailerons due to the motion of the wing is calculated, but with the restriction that the Mach line from either of the leading-edge corners crosses the trailing edge of the control surface on the same side of the wing, unless the control surface is full-span. The derivatives of the hinge moment due to wing motion and to aileron motion are expressed in terms of the derivatives of the wing. A method is given for studying the position of the axis of rotation.

The Oscillating Rectangular Airfoil at Supersonic Speeds. John W. Miles. *U.S., Naval Ordnance Test Station, Inyokern, Calif., NAVORD Report No. 1170 (NOTS 226),* July 21, 1949. 24 pp., illus. 16 references.

Determination of the pressure distribution on a quarter-infinite zero-thickness airfoil with a known downwash that shows harmonic time dependency through the use of a Fourier transform of the linearized potential equation for supersonic flow. The method of solution for the rectangular tip follows the Wiener-Hopf technique and leads to a Green's function. The result may be represented by a definite integral or an expansion in powers of a dimensionless frequency parameter and can be applied to forces and moments on rectangular airfoils of an effective aspect ratio greater than unity. Force and moment coefficients may be expressed in terms of known functions. The one-degree-of-freedom torsional instability indicated by the two-dimensional analysis may disappear for sufficiently small values of the effect aspect ratio.

The Indicial Admittance of a Supersonic Rectangular Airfoil. John W. Miles. *U.S., Naval Ordnance Test Station, Inyokern, Calif., NAVORD Report No. 1171 (NOTS 227),* July 21, 1949. 13 pp., illus. 6 references.

Calculation of the lift and moment coefficients for a rectangular airfoil that is subject to a sudden change in angle of attack in a uniform supersonic stream, or that enters a sharp-edged gust. The pressure distribution along a spanwise strip of a rectangular airfoil due to an angle of attack along a second spanwise strip is calculated. The result, which is basically a Green's function, is used to find the response of the airfoil to an excitation that has an arbitrary distribution in space and time. The indicial admittance (the response of the system to the Heaviside step-function excitation) was obtained from the response of the system to a harmonic excitation and gives the (dimensionless) pressure at a station due to the downwash increment at another station. The results of this process are valid when the Mach lines from the leading-edge corners do not intersect the opposite edges.

Pressure Distribution and Damping in Steady Pitch at Supersonic Mach Numbers of Flat Swept-Back Wings Having All Edges Subsonic. Harold J. Walker and Mary B. Ballantyne. *U.S., N.A.C.A., Technical Note No. 2197,* October, 1950. 62 pp., illus. 10 references.

Gust-Tunnel Investigation of a Wing Model with Semichord Line Swept Back 60°. Harold B. Pierce. *U.S., N.A.C.A., Technical Note No. 2204,* October, 1950. 15 pp., illus. 5 references.

An Approximate Method of Calculating Pressures in the Tip Region of a Rectangular Wing of Circular-Arc Section at Supersonic Speeds. K. R. Czarnecki and James N. Mueller. *U.S., N.A.C.A., Technical Note No. 2211,* October, 1950. 24 pp., illus. 4 references.

Ali a Grande Allungamento. George Bruner. *Alata,* Vol. 6, No. 5, May, 1950, pp. 12–14, illus. In Italian. Résumé of studies by F. Hurel on the aerodynamic efficiency of wings of extremely high aspect ratio.

Air Transportation (41)

Air Transportation and What Is the General Future. Frederick B. Lee. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 517.* 7 pp. Outlook of the C.A.A. on the future of commercial air transportation; results of surveys of the past five years; and an outline of C.A.A. programs for improving and extending air transportation.

The Planned Promotion of Air Transportation. I. Josh Lee. *National Air Review*, Vol. 2, No. 2, October, 1950, pp. 26–32.

United States Overseas Air Cargo Services. VII. N. W. Kendall. *Air Transportation*, Vol. 17, No. 4, October, 1950, pp. 29–34, illus.

B.O.A.C.'s Accounts for 1949–1950. *The Aeroplane*, Vol. 79, No. 2049, September 29, 1950, pp. 350–352, illus.

Aircraft Despatch and Flight Supervision. R. D. Cooling. *Aeronautics*, Vol. 23, No. 3–4, August-September, 1950, pp. 24–29, illus. The American system of flight dispatch and the British reluctance to adopt such a system; duties of the flight controller; advantages of the American system.

Reservations by Electronics. Randolph Hawthorne. *Aviation Age*, Vol. 14, No. 4, October, 1950, pp. 26, 27, illus. Details of the American Airlines Reservisor automatic reservation system.

Airplane Design & Description (10)

Long-Range Commercial Transport Aircraft with High Subsonic Speeds. H. Hertel. *Interavia*, Vol. 5, Nos. 8–9, August-September, 1950, pp. 463–472, illus. 1 reference.

Suggested solutions for the design problem of commercial transport aircraft that satisfy the requirements of the gas-turbine power plants. "Invisible" installation of the turbojet power plants should reduce the drag appreciably. The flying-wing type of aircraft appears to be the best type of design although modifications of the basic plan form will be necessary for economic reasons.

Mathematical Determination of an Aircraft's Skin Shape. Nils Lidbro. *Saab Sonics*, No. 11, July–September, 1950, pp. 19–22, 25, illus.

Equations are found for the horizontal and vertical projections of the airplane body and the important spar sections. The curves are first determined graphically and then replaced by suitable mathematical expressions. The surface is divided up into suitable fields, which allows the use of simple mathematical functions in the development of the equations. The skin surfaces of the wing are usually generated as straight generatrixes that pass over one or more supporting curves in a certain predetermined manner.

What Price Speed? Specific Power Required for Propulsion of Vehicles. G. Gabrielli and Th. von Kármán. *Mechanical Engineering*, Vol. 72, No. 10, October, 1950, pp. 775–781, illus.

Engineering study of the comparative merits of various methods of locomotion. A general trend is demonstrated for the power required per unit gross weight of the vehicle as a function of the maximum speed. Marine, land, and aerial vehicles are considered.

Air Transportation and What Is the Technical Future. Edward C. Wells. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 516B.* 5 pp.

Principal technical problems involved in the design of air transports. New aircraft and power plants will allow substantial increases in performance, but the danger of over-complexity of design is great. Designers and operators should cooperate in providing better standards for aircraft.

Problems Related to Airworthiness Requirements for Commercial Turbine-Engined Airplanes. George W. Haldeman. *Aeronautical Engineering Review*, Vol. 9, No. 11, November, 1950, pp. 33–40.

Airframe Design—Are We in a Rut? Chalmers H. "Slick" Goodlin. *Aviation Age*, Vol. 14, No. 4, October, 1950, pp. 22, 23, illus.

Reducing the parasitic drag of the fuselage by incorporating it into some sort of high-lift device; advantages of configurations such as the Burnelli Loadmaster, the Northrop Flying Wing, the Convair XF-92, and the French Delanne 20-T-2 trainer.

USAF Asks Convertaplane Action; New Interest in Fixed Wing-Copter Configuration Spurs Design Efforts of Small Engineering Groups. *Aviation Week*, Vol. 53, No. 14, October 2, 1950, p. 23, illus.

Turbo-Prop Luscombe. Tom Ashley. *Southern Flight*, Vol. 34, No. 4, October, 1950, pp. 16–18, 37, 39–41, illus. Design characteristics of the Luscombe T-8G-L, military version of the 2-place, all-metal Silvaire, powered by the Boeing Model 502-2 gas turbine with a propeller.

AIRPLANE DESCRIPTIONS

Farnborough 1950; A Review of the Eleventh Society of British Aircraft Constructors' Flying Display and Exhibition. L. L. Th. Huls. *Aircraft Engineering*, Vol. 22, No. 260, October, 1950, pp. 286–291, illus.

Aircraft and Engines on Show. *Aeronautics*, Vol. 23, No. 3-4, August-September, 1950, Supplement, pp. 4A–28A, illus. S.B.A.C. Show, Farnborough.

Farnborough Details. *The Aeroplane*, Vol. 79, No. 2049, September 29, 1950, pp. 346, 347, illus. Cutaway drawings of power controls and pressurized cabin windows of aircraft exhibited at the S.B.A.C. Show.

British Industry Supplement. *The Aeroplane*, Vol. 79, No. 2047, September 1, 1950, pp. 241–246, 253–293, illus.

Italian Air Industry Struggles for Revival. William Green. *Canadian Aviation*, Vol. 23, No. 10, October, 1950, pp. 22, 24, 26, 43, 44, illus.

Turbine Transports of To-Day and To-Morrow. *Interavia*, Vol. 5, Nos. 8–9, August–September, 1950, pp. 456–462, illus. 4 references.

Avro Ashton Four-Engined Turbojet High-Altitude Research Airplane, England. *The Engineer*, Vol. 190, No. 4939, September 22, 1950, pp. 301, 302, illus.

Avro 707B Derwent Delta-Wing Turbojet Research Airplane, England. *Aviation Week*, Vol. 53, No. 15, October 9, 1950, pp. 20, 21, illus.

Beechcraft 50 Twin Bonanza Personal Airplane. *Southern Flight*, Vol. 34, No. 4, October, 1950, pp. 20, 21, 27, 36, illus.

Beechcraft YT-34 Mentor Single-Engined Military Trainer. *Southern Flight*, Vol. 34, No. 4, October, 1950, pp. 24, 25, illus.

Coward Wee Bee Prone-Position 30-Hp. Airplane. Bill Chana. *Skyways*, Vol. 9, No. 11, November, 1950, pp. 14, 15, 43, 44, illus. Pilot's report.

Douglas A2D Skyshark Turboprop Naval Attack Airplane. *Aviation Week*, Vol. 53, No. 17, October 23, 1950, pp. 22, 23, illus.

Fairchild XC-120 Pack Plane Transport. Stanley H. Evans. *Flight*, Vol. 58, No. 2178, September 21, 1950, pp. 332–334, illus.

Fokker S.13 Twin-Engined Crew Trainer, Netherlands. *Aviation Week*, Vol. 53, No. 14, October 2, 1950, p. 28, illus.

Matra R-130 Folding Wing Airplane, France. *Aeronautics*, Vol. 23, No. 3–4, August–September, 1950, p. 34, illus.

The design provides for one pair of wings for subsonic flight and another pair of wings for supersonic flight; the subsonic wings are folded back into the fuselage when the aircraft reaches Mach 0.65.

Mitsubishi 00 Single-Engined Fighter, Japan. (I Designed the Zeke.) Jiro Horikoshi. *Air Trails*, Vol. 35, No. 2, November, 1950, pp. 21–23, 62–66, 68, illus.

Prestwick Pioneer 5-Place Single-Engined Airplane, Scotland. *Aviation Week*, Vol. 53, No. 14, October 2, 1950, p. 24, illus.

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Temco YT-35 Buckaroo Single-Engined Military Trainer. *Southern Flight*, Vol. 34, No. 4, October, 1950, pp. 22, 23, 41, illus.

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COCKPIT & CONTROL CABIN

Ejector Seats in the Saab-18. Kenneth Lindqvist. *Saab Sonics*, No. 11, July–September, 1950, pp. 2–4, cutaway drawings.

CONTROL SYSTEMS

Cable Matches Expansion of Aluminum. *Aviation Week*, Vol. 53, No. 14, October 2, 1950, p. 32, illus. Properties and characteristics of "Hyco-Span" steel aircraft control cable manufactured by American Steel & Wire Co.

LANDING GEAR

A Study of the Response of an Airplane Landing Gear Using the Differential Analyzer. Walter C. Hurty. *Journal of the*

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Scandia's Landing Gear. Bengt Janson. *Saab Sonics*, No. 11, July–September, 1950, pp. 17, 18, illus.

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Airports (39)

Jet Traffic Control. R. R. B. Hoodspith. *Canadian Aviation*, Vol. 23, No. 10, October, 1950, pp. 21, 42, 43, illus.

The Aerocell System of Fueling. Richard E. Stockwell. *Aviation Age*, Vol. 14, No. 4, October, 1950, pp. 34, 35, illus.

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Aviation Medicine (19)

Effects of the Inhalation of Oxygen. L. B. Berger and S. J. Davenport. *U.S., Bureau of Mines, Information Circular No. 7575*, July, 1950. 37 pp. 77 references. A review of the literature on the effects on the human body of breathing oxygen in various concentrations and pressures.

A Comparison of Navigator Activities in the High and Mid-Latitudes. Julien M. Christensen. *U.S., Air Force, Technical Report No. 6027*, August, 1950. 31 pp., illus. 6 references.

Comfortization (23)

A Jet Bleed Aircraft Cabin Conditioner. *Aviation Age*, Vol. 14, No. 4, October, 1950, pp. 28, 29, illus. The aircraft pressurization-air conditioning unit developed by Stratos Corp. for turbojet and turboprop aircraft.

Cooling Package for a Jet Fighter (Aviation Design Progress). Randolph Hawthorne. *Aviation Age*, Vol. 14, No. 4, October, 1950, pp. 30, 31, illus. Stratos NUR12-2 jet-bleed air conditioning and pressurizing unit.

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PAA Experience Proves Flight Simulator Is Realistic and Economical. Scott Flower. *SAE Journal*, Vol. 58, No. 9, September, 1950, pp. 41–45, illus. (Excerpts from a paper: A Review of a Year's Operations of the Curtiss-Wright Dehmel Flight Simulator.)

The Training of College Graduates in Industry. Bernard J. Koehler, in Cooperation with The National Research Committee and The National Educational Committee. *National Office Management Committee, Survey Summary No. 5*, 1948. 40 pp., illus. 30 references. $2.00.

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New Techniques for Electronic Miniaturization. Robert L. Henry, Robert K-F Scal, and Gustave Shapiro. *Institute of Radio Engineers, Proceedings*, Vol. 38, No. 10, October, 1950, pp. 1139–1145, illus.

Uses of Magnetic Tape Recording in Telemetering. Kenneth B. Boothe. *Instrument Society of America, Conference, Buffalo, September 18–20, 1950, Paper No. 50-9-2.* 3 pp.

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Reservations by Electronics. Randolph Hawthorne. *Aviation Age*, Vol. 14, No. 4, October, 1950, pp. 26, 27, illus. Details of the American Airlines Reservisor automatic reservation system.

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Bridged-T Neutralization of Pentode Amplifiers. H. K. Bradford. *Electronics*, Vol. 23, No. 11, November, 1950, pp. 214, 216, illus.

Techniques of Photo-Recording. H. P. Mansberg. *The Oscillographer*, Vol. 12, No. 2, April–June, 1950, pp. 2–17, illus. 10 references.

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A Circuit for Improving the Off-Channel Rejection of a Pulsed-Signal Receiver. D. W. Lynch. *U.S., Naval Research Laboratory, Report No. 3655*, March 23, 1950. 12 pp., illus.

Wide-Range Phase Control with Constant Attenuation by Adjustable Impedance in a Resistance-Loaded Bridged-Tee Network. Myron G. Pawley. *U.S., National Bureau of Standards, Journal of Research*, Vol. 45, No. 3, September, 1950, pp. 193–203, illus. 12 references. (Also available as *Research Paper No. 2123*. U.S. Govt. Printing Office, Washington. $0.10.)

Measurement of Insulation Resistance on Energized Systems. E. L. Brancato and A. T. McClinton. *U.S., Naval Research Laboratory, Report No. 3637*, March 1, 1950. 20 pp., illus. 1 reference.

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A Variable Width Square-Wave Generator. J. Carlisle Hoadley. *Radio & Television News*, Vol. 44, No. 4, October, 1950, pp. 69–71, illus., circuit diagrs.

The Expression of Error Entailed in Measuring Capacitor Temperature-Coefficients. John A. Connor. *U.S., Naval Research Laboratory, Report No. 3664*, May 19, 1950. 9 pp., illus.

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An Electronic A.C. Differential Voltmeter. L. A. Rosenthal and H. S. Zablocki. *Review of Scientific Instruments*, Vol. 21, No. 9, September, 1950, pp. 799–801, illus. 5 references.

The Amplistat and Its Application. III. H. M. Ogle. *General Electric Review*, Vol. 53, No. 10, October, 1950, pp. 41–46, illus.

New Applications for Crystal Diodes. Rufus P. Turner. *Radio & Television News*, Vol. 43, No. 6, June, 1950, pp. 64, 65, 150, 151, illus., circuit diagrs.

The *p*-Germanium Transistor. W. G. Pfann and J. H. Scaff. *Institute of Radio Engineers, Proceedings*, Vol. 38, No. 10, October, 1950, pp. 1151–1154, illus. 13 references.

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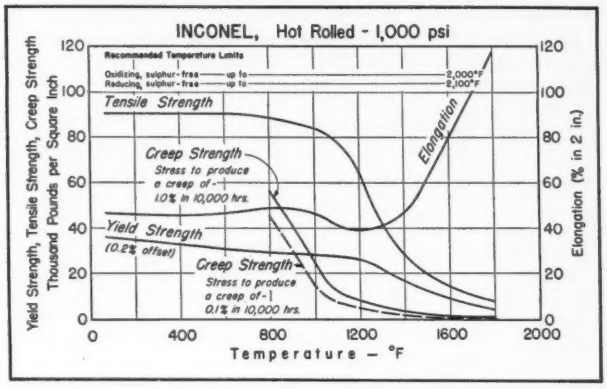

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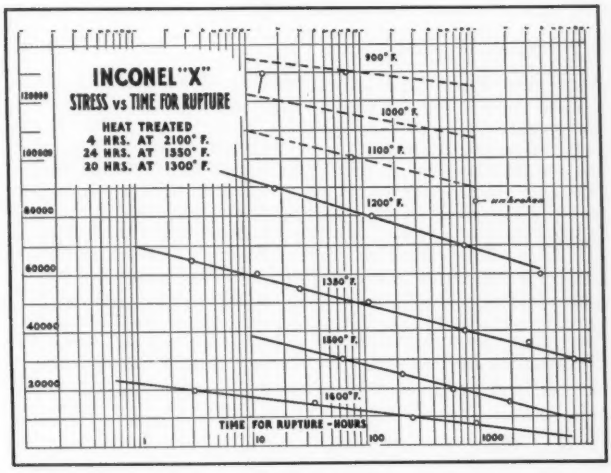

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The Design of Frequency-Compensating Matching Sections. V. H. Rumsey. *Institute of Radio Engineers, Proceedings*, Vol. 38, No. 10, October, 1950, pp. 1191–1196, illus. 5 references.

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The Reflection of an Electromagnetic Plane Wave by an Infinite Set of Plates. III. Albert E. Heins. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 281–291, illus. 6 references.

Radiation from Helices. A. E. Marston and M. D. Adcock. *U.S., Naval Research Laboratory, Report No. 3634*, March 8, 1950. 27 pp., illus. 1 reference.

The Electromagnetic Field Produced by a Helix. R. S. Phillips. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 229–246, illus. 7 references.

Some Magneto-Acoustic Effects in Nickel. T. F. Rogers and S. J. Johnson. *Journal of Applied Physics*, Vol. 21, No. 10, October, 1950, pp. 1067, 1068, illus. 3 references.

Storage of Small Signals on a Dielectric Surface. John V. Harrington. *Journal of Applied Physics*, Vol. 21, No. 10, October, 1950, pp. 1048–1053, illus. 5 references.

Hot-Cathode Arcs in Cesium Vapor. Richard K. Steinberg. *Journal of Applied Physics*, Vol. 21, No. 10, October, 1950, pp. 1028–1035, illus. 12 references.

Equipment

HYDRAULIC & PNEUMATIC (20)

Constant Flow Regulators in Aircraft Hydraulic Systems. John R. McGuire. *Applied Hydraulics*, Vol. 3, No. 6, July, 1950, pp. 24–26, illus.

In a constant-flow regulator, the rate of fluid flow is maintained approximately constant regardless of upstream and downstream pressure. In one type of aircraft constant-flow regulator, fluid entering the system impinges against the face of a piston containing a sharp-edged orifice. As flow increases, the pressure drop across the piston orifice increases, pushing the piston inward to compress a spring, which alters the size of openings within the system. The result is a constant rate of fluid flow into a regulated-flow line. Since the orifice in a constant-flow regulator is larger than that of a fixed resistor valve, there is less danger of clogging.

Emulsions As Hydraulic Fluids. Karl F. Hager and Morris Rosenthal. *Applied Hydraulics*, Vol. 3, No. 7, August, 1950, pp. 18, 19, illus. Investigation of the suitability of water-and-oil emulsions.

Basic Types, Characteristics and Applications of Hydraulic Systems for Aircraft. Frank C. Mittell. *Applied Hydraulics*, Vol. 3, No. 4, May, 1950, pp. 16, 17, 46, illus.

Mechanized Maintenance. Julius Kendall. *Applied Hydraulics*, Vol. 3, No. 9, October, 1950, pp. 42, 43, 61, illus. Inspection and testing of aircraft hydraulic systems with special test machines.

New Hydraulic Pump Has High Output. *Aviation Week*, Vol. 53, No. 16, October 16, 1950, pp. 38, 40, illus.

The Vickers variable displacement, high-capacity hydraulic pump has completed a 1,000-hr. service test on the Convair 240. The pump has a capacity of 2.35 cu.in. per revolution; output is 15.2 gal. per min. at 1,500 r.p.m.

61S Alloy Tubing for Hydraulic Pressure Systems. G. A. Fairbairn and J. J. Sloan. *Applied Hydraulics*, Vol. 3, No. 7, August, 1950, pp. 24–26, illus. Evaluation of 61S aluminum alloy tubing; flaring methods.

Pressure Actuated Switches. II. George A. Starbird. *Applied Hydraulics*, Vol. 3, No. 5, June, 1950, pp. 16–18, illus.

Factors Influencing "O" Ring Operation. Tommy J. McCuistion and Robert E. Allen. *Applied Hydraulics*, Vol. 3, No. 5, June, 1950, pp. 12–14, illus.

Theory and Practice in the Design of Hydraulic Seals. III. R. O. Isenbarger. *Applied Hydraulics*, Vol. 3, No. 4, May, 1950, pp. 24–26, 28, illus.

Selection and Design of Components for Pneumatic Systems. J. Alan Campbell. *Applied Hydraulics*, Vol. 3, No. 6, July, 1950, pp. 22, 23, illus. Definitions and functions of components of senders, receivers, and intermediate devices; possible uses.

Flight Operating Problems (31)

HIGH-SPEED FLIGHT

Five High-Speed Flight Problems. Joseph Flatt. *SAE Journal*, Vol. 58, No. 10, October, 1950, pp. 35–37, illus. (Excerpts from a paper.)

ICE PREVENTION & REMOVAL

Gas Turbine Icing Tests at Mount Washington, New Hampshire. P. M. Bartlett and T. A. Dickey. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 510.* 17 pp., illus.

Organization and test facilities of Project Summit, set up to study jet-engine icing conditions and establish suitable anti-icing systems. The general operation, equipment, unique problems (housing, transportation of supplies, and communications on top of Mt. Washington), and the research work done in the three years of the Project's operation are summarized.

Development of the Anti-Icing System for the J47 Gas Turbine. B. E. Morrell and N. F. Frischhertz. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 509.* 13 pp., illus.

Various anti-icing designs were tested on the G-E J47 turbojet engine in the test facilities atop Mt. Washington. The most promising system was also tested in the G-E B-29 flying test bed. This system consists of air-heated inlet guide vanes, island fairings, strut jackets, and a retractable screen. Tests were run over a range of icing conditions at normal and cruise operating conditions and with the engine idling. Photographs show the condition of the engine during and after tests. The experience with chunks of ice entering the compressor showed that for maximum safety all aircraft components ahead of the compressor inlet require anti-icing protection and that ice should not be allowed to form to a dangerous degree before turning on the anti-icing system.

Heat Requirements of Ice Prevention on Gas-Heated Propellers. Vernon H. Gray. *SAE Quarterly Transactions*, Vol. 4, No. 4, October, 1950, pp. 500–506, illus. 9 references.

Determination of the requirements by analyzing wet-air phenomena. Rates of heated-gas flow which provide sufficient surface heating of the blades are not large enough to give complete ice prevention at the leading edge. Experimental results indicate a method of accurately predicting heat requirements for a specific set of conditions.

On the Ice Wagon. *Flight*, Vol. 58, No. 2179, September 28, 1950, pp. 346–348, illus. Equipment of an R.C.A.F. Canadair North Star for the investigation of icing phenomena and for anti-icing studies.

REFUELING IN FLIGHT

The Application of Pressure Refueling to Flight. George E. Woods-Humphery. *Aeronautical Engineering Review*, Vol. 9, No. 11, November, 1950, pp. 20–23, 32, illus.

Flight Safety & Rescue (15)

Basic Rules for Fire Prevention. D. D. Gordon-Carmichael. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 24, 26, 103–105, illus.

Fire hazards occasioned by aircraft parked either in the open or in a hangar, aircraft during maintenance and overhaul, and refueling. Protective procedures necessary to eliminate or reduce the danger of fire are outlined.

New Way of Fighting Aircraft Fires. Trevor I. Williams. *Indian Skyways*, Vol. 4, No. 8, August, 1950, pp. 39, 41. Use of a special light-explosive charge for cutting through the fuselage of a crashed airplane.

Singed Wings Can't Fly. George H. Tryon, III. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 17–19, 100–102, illus. Fire records of aircraft hangar storage and maintenance.

Which Way Shall the Passenger Face? Kenneth G. Bergin. *Air Pictorial*, Vol. 12, No. 10, October, 1950, pp. 290, 291, illus. The advantages to be gained by the use of backward-facing seats in commercial transports and arguments for and against this seating arrangement.

Research and Development to Promote Safety in Aviation. T. P. Wright. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 508.* 28 pp. 30 references. Survey of current work.

Flight Testing (13)

A Note on the Time Required to Make a Level Speed Measurement with a Turbine-Jet Aircraft. K. J. Lush. *Royal Aeronautical Society, Journal,* Vol. 54, No. 478, October, 1950, pp. 651–655, illus. 1 reference.

The relaxation time for a level speed run in a turbojet aircraft varies rapidly with altitude; it is about five times as great at 40,000 ft. as at sea level. If the speed run is not started at as near to steady level speed as possible, the time required for the run may be several times greater than the corresponding relaxation time.

A Method of Measuring Aircraft Speed and Position Error Using Doppler Radio. E. L. R. Webb. *Canada, Royal Canadian Air Force, Experimental and Proving Establishment, Rockcliffe, Report No. 960 (R.C.A.F Development Interim Report No. D66/1),* September, 1950. 18 pp., illus.

Doppler radio equipment already in use for measuring speeds of meteors was applied to measuring aircraft speed under the restrictions that the aircraft flies a straight path at constant altitude and speed and in a vertical plane that bisects at right angles the line joining transmitter and receiver. Results of several successful tests are tabulated.

Glimpses from the Flight Testing of the SAAB-29. Bengt R. Olow. *Saab Sonics,* No. 11, July–September, 1950, pp. 10–16, illus.

Brake Aids Free-Fall Salvage. *Aviation Week,* Vol. 53, No. 14, October 2, 1950, p. 25, illus.

The N.A.C.A. dive-brake and self-contained parachute system for free-falling models. A rugged "umbrella" with metal ribs bolted to the fabric opens at a predetermined point for slowing up the body. At a predetermined lower speed, a 36-ft. ribbon-type parachute is automatically released from the tail.

Fuels & Lubricants (12)

Effects of Pressure and Other Variables on Determinations of Octane Number. William J. Levedahl. *U.S., National Bureau of Standards, Journal of Research,* Vol. 45, No. 2, August, 1950, pp. 148–153, illus. 4 references. (Also available as *Research Paper No. 2120.* U.S. Govt. Printing Office, Washington. $0.10.)

Experiments were made in an altitude chamber to establish the magnitudes of rating variation with ambient pressure, engine speed, inlet mixture temperature, spark advance, knock intensity, exhaust back pressure, and diameter of the carburetor venturi for several typical fuels. The fuels changed in octane rating as the pressure in the altitude chamber was decreased. The tests showed that supercharging the engines is the only method of obtaining octane ratings identical with sea-level ratings.

X-Ray Fluorescence Analysis of Ethyl Fluid in Aviation Gasoline. L. S. Birks, E. J. Brooks, Herbert Friedman, and R. M. Roe. *Analytical Chemistry,* Vol. 22, No. 10, October, 1950, pp. 1258–1261, illus. 4 references.

X-Ray Absorption Spectrometry for Determination of Tetraethyllead in Gasoline: Investigation of Mono- and Polychromatic Methods and Description of Monochromatic Method for Routine Use. Harold K. Hughes and Frank P. Hochgesang. *Analytical Chemistry,* Vol. 22, No. 10, October, 1950, pp. 1248–1258, illus. 27 references.

Determination of Tetraethyllead in Gasoline by X-Ray Absorptiometry. George Calingaert, F. W. Lamb, H. L. Miller, and G. E. Noakes. *Analytical Chemistry,* Vol. 22, No. 10, October, 1950, pp. 1238–1248, illus. 13 references.

Rapid Polarographic Determination of Tetraethyllead in Gasoline. Kent A. Hansen, Thomas D. Parks, and Louis Lykken. *Analytical Chemistry,* Vol. 22, No. 10, October, 1950, pp. 1232, 1233, illus. 9 references.

Rapid Determination of Tetraethyllead in Aviation Gasoline. V. A. Smith, W. E. Delaney, W. J. Tancig, and J. C. Bailie. *Analytical Chemistry,* Vol. 22, No. 10, October, 1950, pp. 1230, 1231, illus. 11 references.

A Direct-Reading Polarograph for Determination of Tetraethyllead in Gasoline. E. B. Offutt and L. V. Sorg. *Analytical Chemistry,* Vol. 22, No. 10, October, 1950, pp. 1234–1237, illus. 6 references.

Cylinder Performance—Compression Ratio and Mechanical Octane-Number Effects. S. D. Heron and A. E. Felt. *SAE Quarterly Transactions,* Vol. 4, No. 4, October, 1950, pp. 455–486, Discussion, pp. 486–499, illus. 7 references.

Comparison of data obtained with a cylinder of passenger car size, using compression ratios of 5.7–1 to 15–1 with four combustion-chamber types. Fuel economy and knocking data are presented in tables and graphs.

Condensed Gas Calorimetry. I—Heat Capacities, Latent Heats and Entropies of Pure Para-Hydrogen from 12.7 to 20.3 °K.; Description of the Condensed Gas Calorimeter in Use in the Cryogenic Laboratory of the Ohio State University. Herrick L. Johnston, John T. Clarke, Ellis B. Rifkin, and Eugene C. Kerr. *American Chemical Society, Journal,* Vol. 72, No. 9, September, 1950, pp. 3933–3938, illus. 26 references.

The Vapor Pressure of Normal Hydrogen from the Boiling Point to the Critical Point. David White, Abraham Solomon Friedman, and Herrick L. Johnston. *American Chemical Society, Journal,* Vol. 72, No. 9, September, 1950, pp. 3927–3930, illus. 14 references.

Aviation Gas-Turbine Engine Lubricants. A. E. Smith. *Aero Digest,* Vol. 61, No. 4, October, 1950, pp. 46, 48, 81, 83–86, illus. Review of the lubrication problems of gas-turbine engines, the lubricants now in use, and needs for improved lubricants and lubricating systems.

Instruments (9)

A Simplified Thermocouple for Temperature Measurements in High Velocity Gas Streams. H. M. Beede and C. R. Droms. *Instrument Society of America, Conference, Buffalo, September 18–20, 1950, Paper No. 50-13-3.* 4 pp., illus.

Design of a relatively large thermocouple of sturdy construction to measure total temperature. Tests made on bare-wire thermocouples similar to those in current use indicated that in rotating the thermocouple about its axis perpendicular to the airflow there was a drop in the temperature of the thermocouple where the airflow is parallel to the plane of the wires. Thermocouples were constructed of the spade-type and of a type with the wires enclosed in a stainless steel tube with a large entrance hole and a small exit hole. Results of the studies are presented graphically. Of the types tested, the "closed-spade" type with $^1/_4$-in. shield and 24-gage wires was the best design. It exhibited a recovery factor of 0.95 ± 0.01 over a range of velocities from 450–575 ft. per sec. and through an angle of yaw of $\pm 45°$.

Design of a Device for Measurement of Free-Stream Static Pressure at Supersonic Speeds. M. V. Morkovin. *Aeronautical Engineering Review,* Vol. 9, No. 12, pp. 25–28, illus.

Quelques Expériences sur la Non-Linéarité des Fils Chauds. R. Betchov and W. Welling. (*Delft, Technische Hogeschool, Laboratorium voor Aero- en Hydrodinamica, Mededeling No. 66.*) *K. Nederlandsche Akademie van Wetenschappen, Proceedings,* Vol. 53, No. 4, 1950, pp. 432–439, illus. 1 reference. In French. Reprint. Experimental investigation of the nonlinearity of hot wires.

Some Design Considerations in Connection with the Use of High Speed Thermometry for Telemetering. Vernon C. Westcott. *Instrument Society of America, Conference, Buffalo, September 18–20, 1950, Paper No. 50-9-3.* 2 pp., illus.

Impact-Pressure Interpretation in a Rarefied Gas at Supersonic Speeds. E. D. Kane and G. J. Maslach. *U.S., N.A.C.A., Technical Note No. 2210,* October, 1950. 37 pp., illus. 16 references.

Diaphragm-Type Micromanometer with Electronic Pickup. *U.S., National Bureau of Standards, Technical News Bulletin,* Vol. 34, No. 10, October, 1950, pp. 137–139, illus.

The NACA Oil-Damped V-G Recorder. Israel Taback. *U.S., N.A.C.A., Technical Note No. 2194,* October, 1950. 28 pp., illus. 2 references.

Calorimeter for Some Corrosive Liquids. B. H. Sage and E. W. Hough. *Analytical Chemistry,* Vol. 22, No. 10, October, 1950, pp. 1304–1309, illus. 13 references.

Heat capacity of corrosive liquids may be measured at temperatures up to 400 °F. Results will have an error of less than 1 per cent if the rates of corrosion and decomposition of the fluid under study are small.

Air Driven Gyroscope Is Non-Toppling. *Product Engineering*, Vol. 21, No. 10, October, 1950, pp. 128, 129.

A directional gyroscope manufactured by Smiths Aircraft Instruments, Ltd., which has complete freedom of the inner gimbal ring up to 85°. The instrument is almost fully aerobatic and operates on a suction of $3^1/_2$–$4^1/_2$-in. mercury.

Rupture-Proof Bellows-Type Flow Meters. Claude B. Nolte. *Instrument Society of America, Conference, Buffalo, September 18–20, 1950, Paper No. 50-16-1.* 4 pp., illus.

Wire Strain Gages for Elevated Temperature Service. D. J. DeMichele. *Product Engineering*, Vol. 21, No. 10, October, 1950, pp. 115–117, illus.

Fabrication and mounting of electric resistance wire strain gages for high-temperature work in gas-turbine engines. The gages available commercially cannot be used at temperatures above 750°F. Some gages for high-temperature work have been built; their fabrication and mounting is precise, time-consuming, and expensive. General Electric Co. has built a high-temperature gage that can be quantity-produced and need not be mounted immediately after fabrication. It consists of 85 per cent platinum-15 per cent iridium wire, fabricated to mica in a closely spaced grid. The wires are bonded to the mica with Sauereisen No. 31 cement. The gage is cemented to the turbine bucket, and the lead wires are brought out through the center of the rotating shaft and connected to the slip ring assembly.

Bendix' Three-in-One Flying Aid; "Omni-Mag" Combines Functions of Three Instruments. George L. Christian. *Aviation Week*, Vol. 53, No. 15, October 9, 1950, pp. 44, 45, illus.

A Variational Problem for the Roots of a Cubic Equation; A Contribution to the Theory of Servomechanisms. Hans Buckner. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 293–296.

Designing an Eddy Current Clutch Servo. Alfred S. Gutman. *Machine Design*, Vol. 22, No. 10, October, 1950, pp. 109–115, 154, illus. 3 references.

This clutch design uses a radial air gap and a floating rotor assembly; it permits a close air gap and develops a high torque. A preliminary model was made up with two coils enclosed in a soft iron container rotating in opposite directions on bevel gears from a $^1/_{20}$-hp., 10,000 r.p.m., 24-volt d.c. motor. In order to predict the power output of the clutch and to arrive at an optimum design, a theoretical study of the basic design was carried out. The magnetic flux inside the strip for stationary conditions was established, and the analysis extended to a moving strip. For a rotating disc, maximum power would be obtained with 14 poles. Calculations indicate that maximum effective power is transmitted at operating conditions of $8^1/_2$ phase shift in the Z-component of the magnetic force. The final design consideration was the air gap between the poles. On the basis of these theoretical calculations, the clutch was redesigned. Test results on the final design showed that the clutch would work well at light leading conditions but was inadequate at heavier loads.

Laws & Regulations (44)

Critical Reflexions on Air Cabotage. Alex Meyer. *Interavia*, Vol. 5, Nos. 8–9, August-September, 1950, pp. 429,430.

Why Patents. W. R. Lane. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 511.* 6 pp. Basic information on patents, their history, and their position in our present industrial activities.

Machine Elements (14)

Why Machine Parts Fail. VI—Torsional Fractures. Charles Lipson. *Machine Design*, Vol. 22, No. 10, October, 1950, pp. 97–100, illus. 2 references.

BEARINGS

Investigation of Bearing Materials Under Various Degrees of Lubrication in the Low-Speed Range. Louis A. Nowell, Jr. *American Society for Testing Materials, Bulletin*, No. 168, September, 1950, pp. 47–53, illus. 4 references.

Oil Holes and Grooves in Plain Journal Bearings. S. A. McKee. *American Society of Mechanical Engineers, Transactions*, Vol. 72, No. 7, October, 1950, pp. 1025–1034, illus. 6 references.

Factors When Considering Anti-Friction Bearings for Oscillating Service. F. G. Patterson. *Product Engineering*, Vol. 21, No. 10, October, 1950, pp. 141–143, illus.

FASTENINGS

The Unification of Fasteners. Sir A. Bowlby and T. Affleck. *Aeronautics*, Vol. 23, No. 3–4, August-September, 1950, pp. 30–33, illus. Suggestions for the standardization of dimensions on bolts, nuts, and screws; implications of the Anglo-American agreement to standardize screw threads.

Expanding Tube Grips Sides of Undersize Hole; Used As Instrument Shaft, Dowel Pin, Cotter Pin and Pivot Pin. *Product Engineering*, Vol. 21, No. 10, October, 1950, p. 164, illus.

FRICTION

Friction. F. P. Bowden. *Nature*, Vol. 166, August 26, 1950. 11 pp., illus. Reprint. A general review.

GEARS & CAMS

Film Thickness Between Gear Teeth. M. D. Hersey and D. B. Lowdenslager. *American Society for Mechanical Engineers, Transactions*, Vol. 72, No. 7, October, 1950, pp. 1035–1042, illus. 7 references.

Helical Gear Design Chart for 90° Shaft Angle. Wayne A. Ring. *Product Engineering*, Vol. 21, No. 10, October, 1950, p 161, illus.

Maintenance (25)

A K.L.M. Servicing Innovation; Some Details of a Test Trolley for the Wright R-2800 Engines of the DC-6. *Aircraft Engineering*, Vol. 22, No. 260, October, 1950, pp. 301, 302, illus.

Maintaining the (de Havilland) Comet. Rex King. *The Technical Instructor*, Vol. 5, No. 9, September, 1950, pp. 3–9, illus.

Boeing Service Guide, No. 36, September, 1950. 12 pp., illus. Boeing 377 Stratocruiser.

Management & Finance (45)

Factory Personnel Problems; Human Factors for Maximum Producibility. L. O. Stockford and K. R. Kunze. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 512.* 30 pp., illus. 22 references.

An analysis of the relationship of one measure of age to one criterion of employee adjustment; chronological age is the measure of age considered. The study presents only observational data and no conclusive proof.

Industrial Mobilization. W. S. Friedman. *The Pegasus*, Vol. 16, No. 3, September, 1950, pp. 12–15, illus.

Materials (8)

Approximate Solutions of Problems of Plane Plastic Flow. P. G. Hodge, Jr. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 257–264, illus. 10 references.

A method of approximating the stress and velocity fields in problems of plane plastic flow and extension of the concept that a discontinuous solution is possible in some cases admitting a continuous solution. The deformed pattern of an originally square grid is found by using a discontinuous solution. The continuous solution of the stress and incipient-velocity fields of an instantaneous state problem is compared with several possible discontinuous solutions. The single-shock and double-shock solutions are presented for the case of a smooth rigid wedge pressed into a semi-infinite perfectly plastic material under conditons of strain. The variation between the continuous and discontinuous computed solutions is of approximately the same order as the variation between the continuous solution and the experimental solution.

On the Dislocation, the Group of Holonomy and the Theory of Yielding. Kazuo Kondo. *Japan Society for Applied Mechanics, Journal*, Vol. 3, No. 17, May, 1950, pp. 107–110, illus. 2 references. In English.

Derivation of expressions for yielding phenomena based on the theory of incompatability and dislocation of an elastic body.

Systems Engineering

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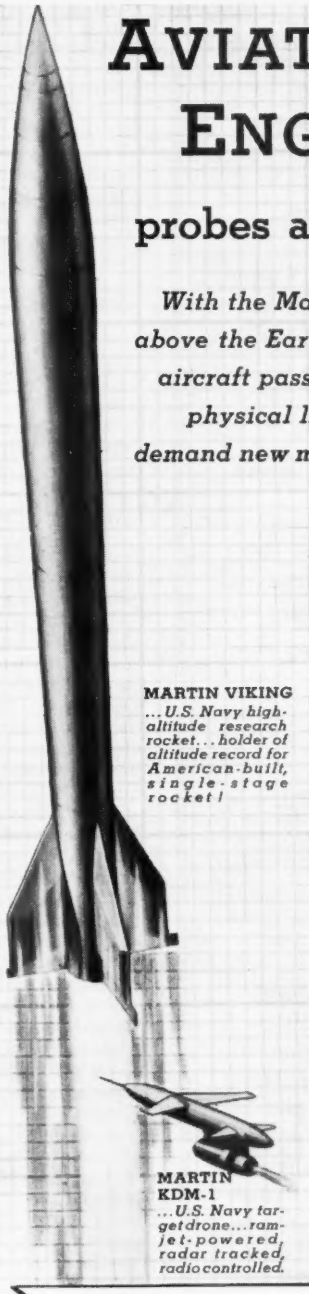

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Directory of Materials. *Machine Design*, Vol. 22, No. 10, October, 1950, pp. 252–324, 326, 328, 330, 332, 334, 336.

Materials by tradename, their characteristics, applications and producing companies; standard A.I.S.I. stainless steels, their characteristics and applications; stainless steel tradenames and producing companies; materials classified according to type; and names and addresses of producers along with notation of products.

CERAMICS & CERAMALS

Sintering Mechanism Between Zirconium Carbide and Columbium. H. J. Hamjian and W. G. Lidman. *U.S., N.A.C.A., Technical Note No. 2198*, October, 1950. 29 pp., illus. 9 references.

Metal Ceramics. *Machine Design*, Vol. 22, No. 10, October, 1950, pp. 101, 102, illus. Analysis of properties, machining, applications, and limitations of Haynes Stellite Metamic LT-1.

METALS & ALLOYS

Properties of Metals at Elevated Temperatures. G. V. Smith. *Mechanical Engineering*, Vol. 72, No. 10, October, 1950, pp. 799–804, illus. 14 references.

Comprehensive outline of the problems caused by subjecting metals to high temperatures. The most important considerations are the strength of the material and the working stress to be applied. Rate of strain becomes increasingly important as temperature rises. At slow rates of strain, the fracture of the material is likely to be abrupt, with no previous indication that fracture is about to occur. A study of creep showed that deformation continues to occur with time in service at elevated temperatures. If the material is designed for a limited service life, the working stress must be chosen which does not allow a certain deformation to be exceeded. The relations between creep and fracture time and deformation and time are investigated with experimental data obtained on 18 Cr-8 Ni-Mo stainless steel, and the results are presented graphically. Scaling, corrosion, microstructural changes, and surface changes were investigated.

Iron-Base Heat Treatable Alloy (Discalloy) Has Good High Temperature Strength. E. F. Losco. *Materials & Methods*, Vol. 32, No. 4, October, 1950, pp. 65–69, illus.

The Oxidation of Zirconium at High Temperatures. Daniel Cubicciotti. *American Chemical Society, Journal*, Vol. 72, No. 9. September, 1950, pp. 4138–4141, illus. 15 references.

Surface Hardening of Titanium. H. W. Worner. *The Australasian Engineer*, July, 1950, pp. 49–51, illus. 9 references. Reprint.

A study of the hardening of titanium and titanium-base alloys by oxygen impregnation treatments. The process consists of heating the metal at 850°–1,000°C. in air or oxygen at a pressure between 10^{-3} mm. and 10^{-2} mm. mercury, or in an inert gas containing a controlled amount of oxygen. The material is then slow-cooled in the atmosphere in which it was heated. The hardening is caused by the formation of a solid solution of oxygen in the titanium. The melting point of the titanium is increased considerably by the addition of oxygen. The bonding between the oxygen and the titanium is a resonating system of the metallic-covalent type. A geometrical investigation of the problem of accommodating the oxygen atoms in the titanium lattice shows that the oxygen is dispersed in the titanium in the form of an octahedral interstitial solid solution.

A Survey of the Constitutional Diagram of the Chromium-Titanium System. Marion K. McQuillan. *Australia, Department of Supply, Aeronautical Research Laboratories, Report No. SM. 157*, June, 1950. 14 pp., illus. 3 references.

Investigation of the binary system of chromium-titanium by a study of quenched samples. At temperatures of 1,360°–1,400°C., there is almost complete mutual solubility of the body-centered cubic chromium and the body-centered cubic β-form of titanium. On quenching, the solution breaks up to form Cr_3Ti_2 and a body-centered cubic-solution based either on the chromium or β-titanium lattice. This action can be explained by the high temperature required for solubility and the assistance provided by the

thermal motion of the atoms for the assimilation of foreign atoms by the lattice. The compound itself is hard and brittle; the chromium-rich solutions also tended to brittleness. Alloys based on the β-titanium solid solution were strong and tough, could be hot-worked fairly easily, and could be machined. No evidence was found of the existence of Cr_2Ti_3.

Zirconium Offers Interesting Properties and Possibilities. *Materials & Methods*, Vol. 32, No. 4, October, 1950, pp. 63, 64, illus.

What's Ahead in Metals. *Product Engineering*, Vol. 2, No. 10, October, 1950, pp. 87–95, illus.

New Structural Metals. J. J. Harwood. *Product Engineering*, Vol. 21, No. 10, October, 1950, pp. 96–102, illus. 9 references. Properties, processing, and fabrication of titanium, zirconium, molybdenum, and their alloys.

Modern Aircraft Materials. G. B. Evans. *The Technical Instructor*, Vol. 5, No. 9, September, 1950, pp. 10–14, illus. General structural consideration of steels and aluminum and magnesium alloys used in air frames and aircraft power plants.

Chromium Is Plated Directly on Aluminum by New Process (Cro-Plate). T. C. Du Mond. *Materials & Methods*, Vol. 32, No. 4, October, 1950, pp. 56, 57, illus.

Coating of Steel with Aluminum. S. L. Case. *Steel Processing*, Vol. 36, No. 9, September, 1950, pp. 435–439, 451, illus. 12 references.

Processes available for superimposing a skin of aluminum on a steel base. Steel that is clad with aluminum by the calorizing method (coating the surface by diffusion) is analyzed for its scaling resistance and its resistance to a hydrogen sulfide atmosphere; the results are tabulated. Hot-dip coatings, aluminizing, and the Al-Fin process are defined.

The Propagation of Plastic Deformation in Solids. Theodore von Kármán and Pol Duwez. *Journal of Applied Physics*, Vol. 21, No. 10, October, 1950, pp. 987–994, illus. 6 references.

Analysis of the stress wave effected by the longitudinal impact at the end of a cylindrical bar to determine the stress and strain beyond the elastic limit of the material. A method is derived for computing the instantaneous stress distribution along the bar during impact. The velocity of the plastic wave and the maximum strain are determined as a function of the velocity of impact. A critical impact velocity exists, and a tension impact greater than this critical impact will cause an instantaneous breakdown of the material. Results are given of experiments carried out concurrently with the theoretical study.

The Mechanisms of Diffusion. P. F. Fensham. *The Australasian Engineer*, July, 1950, pp. 41–43, illus. 17 references. Reprint.

Diffusion in solids takes place with the relative movement past each other of the units composing the lattice. Several diffusion mechanisms are investigated in terms of the atomic arrangements in the solids. For ideal crystals, diffusion probably takes place by rotation and substitution. The actual crystals contain two main types of defects: those involving the presence of interstitial atoms in the lattice, and those involving the presence of vacant lattice sites. Theoretical and experimental evidence shows that diffusion may occur by atomic rearrangement within the lattice because of these defects.

The Structure of a Metal Surface. A. J. W. Moore. *The Australasian Engineer*, July, 1950, pp. 37–40, illus. 19 references. Reprint.

Many surface properties of metals can be explained in terms of the probability fields of electrons and the resulting fields of force. A discussion of the Van der Waals forces provides a concept of a theoretical simplified surface—a plane of atoms regularly spaced associated with an attractive field that diminishes rapidly away from the surface. The true nature of a surface depends upon its mode of finishing; real surfaces show large irregularities in contour, relatively thick films of foreign atoms, and plastic deformation at or near the surface. Sensitive optical and profile-tracing methods are available for measuring the magnitude of the surface irregularities. Comparison of the predicted surface conditions with those established by measurement indicates that each specimen must be treated as a special case: a surface that appears smooth may contain irregularities many times greater than the atomic distance.

The Kinetics of Decomposition of Gases at Metal Surfaces. M. F. R. Mulcahy. *The Australasian Engineer*, July, 1950, pp. 67–70. 29 references. Reprint.

A review of the theory. Experimental results on the deposition of carbon from methane and of nitrogen from ammonia on metallic surfaces are in good agreement with existing theory. A comparison between the reaction rate and the diffusion rate indicates that the maintenance of a layer of the gaseous reactant on the metallic surface does not require an unusually high rate of decomposition, even at the start of the process. Certain factors may be present, either in the metal or on the surface, which will lower the reaction rate below that necessary to maintain the maximum rate of diffusion.

NONMETALLIC MATERIALS

Redux Bonding of Aircraft Structures. C. J. Moss. *Royal Aeronautical Society, Journal*, Vol. 54, No. 478, pp. 640–646, Discussion, pp. 646–650, illus. Gluing process for all-metal structures developed by Aero Research Ltd. and used in the de Havilland Comet turbojet air liner.

List of Publications on Glue, Glued Products, and Veneer. *U.S., Forest Products Laboratory, Madison, Wis., Report No. R513*, May, 1950, 17 pp.

List of 201 publications available from the Forests Products Laboratory, the U.S. Govt. Printing Office, and trade journals on the development of waterproof glues, preparation and application of glues, plywood manufacturing problems, and related topics. The papers cover research work from 1922–1950 and are listed under eight headings.

Effective Stress and Effective Strain in Relation to Stress Theories of Plasticity. G. N. White, Jr., and D. C. Drucker. *Journal of Applied Physics*, Vol. 21, No. 10, October, 1950, pp. 1013–1021, illus. 16 references.

Investigation of how incremental stress-strain relations derived in terms of criterion of yield or of further plastic deformation can be used in a systematic way to develop consistent and reasonable definitions of effective stress and effective strain. Choosing the loading function to be a function of the stress components only leads to the definition of effective stress in terms of the stress components and effective strain in terms of the history of strain. These definitions should lead to better understanding of tests on isotropic and anisotropic work-hardening materials.

PROTECTIVE COATINGS

Laboratory Testing of the Rain Erosion Resistance of Aircraft Finishes. Jack K. Grace and George C. Frey. *American Society for Testing Materials, Bulletin*, No. 168, September, 1950, pp. 56–63, illus. 12 references.

Eroded areas on aircraft due to the effects of rain have been chiefly the surfaces of low-pressure glass cloth-polyester laminates and organic finishing materials. The water-jet tester and the whirling-arm tester are used for laboratory investigations. The water-jet tester sends a high-velocity jet of water on a test specimen; the jet may be modulated. The whirling-arm tester moves the specimen through a water spray at high speeds. Test data from these two types of equipment are compared; the time for erosion failure of several plastics is found to vary as the reciprocal of a large power of the velocity. Specific test results are tabulated.

SANDWICH MATERIALS

Analysis of Shear Strength of Honeycomb Cores for Sandwich Constructions. Fred Werren and Charles B. Norris. *U.S., N.A.C.A., Technical Note No. 2208*, October, 1950. 18 pp., illus. 4 references.

Meteorology (30)

On the Dynamics of the General Atmospheric Circulation. C. H. B. Priestley. *Australian Journal of Scientific Research, Series A, Physical Sciences*, Vol. 3, No. 1, March, 1950, pp. 1–18, illus. 19 references.

A Remarkable Thunderstorm Flight Record. U. Radok. *Australian Journal of Scientific Research, Series A, Physical Sciences*, Vol. 2, No. 4, December, 1949, pp. 550–563, illus. 6 references.

Records of a sailplane flight in a thunderstorm at Benalla, Victoria, are examined and compared with thunderstorm records of Florida. The lognormal distribution of the data is used to estimate the probability of large downdraft velocities.

Progress in Dynamic Meteorology. Jule G. Charney. *American Meteorological Society, Bulletin*, Vol. 31, No. 7, September, 1950, pp. 231–236.

Progress in Research in Synoptic Meteorology. E. Palmen. *American Meteorological Society, Bulletin*, Vol. 31, No. 7, September, 1950, p. 237.

Further Studies of the Movement and Formation of Hurricanes and Their Forecasting. Herbert Riehl and Newton M. Burgner. *American Meteorological Society, Bulletin*, Vol. 31, No. 7, September, 1950, pp. 244–253, illus. 13 references.

A Comparison of Precipitation from Maritime and Continental Air. George S. Benton and Robert T. Blackburn. *American Meteorological Society, Bulletin*, Vol. 31, No. 7, September, 1950, pp. 254–256, illus. 2 references.

Methods of Stratus and Fog Forecasting for Payne Field (Farouk Airport) and Vicinity, Egypt. Albert Simon. *American Meteorological Society, Bulletin*, Vol. 31, No. 7, September, 1950, pp. 257–263, illus.

Progress in Studies of the Airflow in Upper Air Research. C. T. Elvey. *American Journal of Physics*, Vol. 18, No. 7, October, 1950, pp. 431–437, illus. 11 references.

Military Aviation (24)

A Basis of Unity. Eugene E. Wilson. *U.S. Naval Institute, Proceedings*, Vol. 76, No. 9, September, 1950, pp. 961–967.

Navigation (29)

The Celestial Triangle; Solution by Slide Rule. Robert A. MacGregor and Edwin A. Beito. *U.S. Naval Institute, Proceedings*, Vol. 76, No. 9, September, 1950, pp. 1009–1015, illus.

Flying a 'Bug' Instead of a Beam. F. Lee Moore. *Aviation Week*, Vol. 53, No. 17, October 23, 1950, pp. 57–62, illus.

Operations of the A.N.D.B. Pictorial Computer, a navigational device in which a moving-position-indicator draws a line on the pilot's map, showing position and course at any instant; it is based on the omnibearing distance system.

Ordnance & Armament (22)

Fighter Armament. II—German Equipment in the Second World War; Inefficient Intelligence. III—Guns v. Rockets. A. R. Weyl. *Flight*, Vol. 58, Nos. 2178, 2180, September 21, October 5, 1950, pp. 338–340; 379–381, 388; cutaway drawings; illus.

Personal Flying (42)

The Ultra Light Aircraft Association. E. L. Mole. *Shell Aviation News*, No. 147, September, 1950, pp. 7–11, illus.

Photography (26)

A Kerr Cell Camera and Flash Illumination Unit for Ballistic Photography. H. F. Quinn, W. B. McKay, and O. J. Bourque. *Journal of Applied Physics*, Vol. 21, No. 10, October, 1950, pp. 995–1001, illus. 5 references.

An experimental camera designed to photograph projectiles under conditions of strong ambient illumination. The optical arrangements and electrical circuits of the apparatus are described. The pulse-forming network is of conventional design; the pulse transformer circuit applies an operating voltage to the Kerr Cell of 36 kilovolts amplitude and 1.9 microsec. duration. Details are given of experiments and suggestions for improving the apparatus.

Techniques of Photo-Recording. H. P. Mansberg. *The Oscillographer*, Vol. 12, No. 2, April–June, 1950, pp. 2–17, illus 10 references.

Practices of photographing from the cathode-ray oscillograph; recording material and processing techniques, reduction of undesired illumination, continuous motion and single recording, and methods of imprinting time calibration and identification.

Air Survey; The Application of Modern Techniques to Surveying and Mapping. C. A. Hart. *Royal Aeronautical Society, Journal*, Vol. 54, No. 478, October, 1950, pp. 613–634, Discussion, pp. 634–639, illus. 17 references.

Techniques and Results of Aeromagnetic Surveying. J. R. Balsey. *Shell Aviation News*, No. 147, September, 1950, pp. 15–17, illus.

Stereo Strip Camera Has Military, Civilian Uses. George W. Goddard. *SAE Journal*, Vol. 58, No. 9, September, 1950, pp. 64–67, illus. (Based on a paper: Stereophotography.)

Power Plants

High-Altitude Aircraft Oil Systems. F. E. Carroll, Jr. *SAE Quarterly Transactions*, Vol. 4, No. 4, October, 1950, pp. 519–529, illus. 17 references.

Review of reciprocating- and turbine-engine oil pump design and performance characteristics. Both the closed-circuit type and the hot-tank type of aircraft oil systems provide improved high-altitude operation over the conventional oil systems. The closed-circuit system is the most desirable for high-altitude operation because of its satisfactory performance characteristics and design simplicity.

Engine Production of French Companies. *Aviation Week*, Vol. 53, No. 15, October 9, 1950, p. 37.

JET & TURBINE (5)

Effect of Heat-Capacity Lag on a Variety of Turbine-Nozzle Flow Processes. Robert B. Spooner. *U.S., N.A.C.A., Technical Note No. 2193*, October, 1950. 24 pp., illus. 3 references.

Effect of Heat and Power Extraction on Turbojet-Engine Performance. III—Analytical Determination of Effects of Shaft-Power Extraction. Stanley L. Koutz, Reece V. Hensley, and Frank E. Rom. *U.S., N.A.C.A., Technical Note No. 2202*, October, 1950. 49 pp., illus. 6 references.

Current Turboprop Power-Plant Installations. F. H. Sharp. *Aeronautical Engineering Review*, Vol. 9, No. 11, November, 1950, pp. 41–44, illus.

Turboprop Installation Problems. F. Herbert Sharp. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 515.* 6 pp., illus.

Comparison of Turbine-Propeller Engines with Various Cycle Arrangements for Subsonic Flight Speeds. Tibor F. Nagey. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 513.* 17 pp., illus. 5 references.

A study of the effects on aircraft operating performance of the application of reheat or regeneration, or a combination of the two, to the turboprop engine. The analysis of the basic reheat, regenerative, and regenerative-plus-reheat turboprops covered flight speeds of 200–600 m.p.h., altitudes of 0–50,000 ft., and turbine inlet temperatures of 2,000°–2,500°R. for a compressor ratio range of 6–42. The presence of the regenerator in the cycle reduced the required compressor pressure ratio for maximum range to extremely low values. Operating the engine with a regenerator effectiveness of 0.5 gave little improvement in range over that of the basic engine; greater improvements occurred with the more complex reheat-plus-regenerative engine. At an altitude of 30,000 ft., the basic turboprop engine gave greater range than the simple turbojet at flight speeds up to 400 m.p.h.; at speeds of 400–500 m.p.h., the engines were competitive; at speeds above 500 m.p.h., the turbojet gave greater range.

The Development of Jet Helicopters in France. André Charriou. *Aircraft Engineering*, Vol. 22, No. 260, October, 1950, pp. 292–295, illus.

A modification of the Doblhoff (pressure jet) system is used in these helicopters developed by S.N.C.A.S.O. The air compressor, operated from either a reciprocating or gas-turbine engine, is installed in the fuselage. Air from this compressor is delivered through the hub and blades to combustion chambers at the rotor tips; fuel is injected into the combustion chamber as a liquid. Two prototype machines have been built, and a third type is under construction.

Armstrong Siddeley's Adder Turbojet. Paul H. Wilkinson. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 43, 96, 97, illus.

Pratt & Whitney Turboprop (PT-2, Navy T-34). Ira F. Angstadt. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 28, 94, illus.

Turboprops Recommended for 1955 Turbine Transports. R. M. Hazen. *SAE Journal*, Vol. 58, No. 9, September, 1950, pp. 27–30, illus. (Excerpts from a paper: The Case for the Turboprop Engine.)

Jet Engine Thrust—Measured in Flight. William Wahl and M. A. Sulkin. *SAE Journal*, Vol. 58, No. 9, September, 1950, pp. 46–48, illus. (Excerpts from a paper: Ground and Flight Evaluation of the Performance of Jet Powerplant Installations and Some Installation Factors Affecting Output.)

British Views on Jet Engine Design. G. Geoffrey Smith. *SAE Journal*, Vol. 58, No. 9, September, 1950, pp. 49, 50.

The Jet Engine Comes of Age. R. P. Kroon. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 40–42, 87–90, illus.

Development of a Gas Turbine. H. T. Chapman. *Hawker Siddeley Review*, Vol. 3, No. 3, September, 1950, pp. 3–7, illus. Design and development hurdles in the gas-turbine engine; turbine and compressor testing; combustion problems; and blade vibration.

Present-Day Gas-Turbine Engines. *Interavia*, Vol. 5, Nos. 8–9, August-September, 1950, pp. 472–477, illus. 2 references.

Turbojet Afterburning Without an Afterburner. Heinz E. Schmitt. *Aeronautical Engineering Review*, Vol. 9, No. 12, pp. 18–24, illus. 12 references.

RECIPROCATING (6)

A Study of Mixture Distribution. R. W. Donahue and R. H. Kent, Jr. *SAE Quarterly Transactions*, Vol. 4, No. 4, October, 1950, pp. 546–557, Discussion, 557, 558, 570, illus. 7 references.

Uneven distribution of the fuel and air to the cylinders. Design factors, such as the position of the choke valve and its mounting, can alter the mixture distribution more than changes in engine speed, mixture temperature, and fuel volatility. The lighter components of the fuel are as unevenly distributed as the heavier components.

Cylinder Performance—Compression Ratio and Mechanical Octane-Number Effects. S. D. Heron and A. E. Felt. *SAE Quarterly Transactions*, Vol. 4, No. 4, October, 1950, pp. 455–486, Discussion, pp. 486–499, illus. 7 references.

Comparison of data obtained with a cylinder of passenger car size, using compression ratios of 5.7–1 to 15–1 with four combustion-chamber types. Fuel economy and knocking data are presented in tables and graphs.

Precombustion Reactions in a Motored Engine. D. L. Pastell. *SAE Quarterly Transactions*, Vol. 4, No. 4, October, 1950, pp. 571–583, Discussion, 584–587, illus. 43 references.

End-gas reaction studies. The factors affecting precombustion reactions in a motored engine are similar to those affecting a fired engine. Fuels show the same type of correlation between tendency to knock in a fired engine and susceptibility toward autoignition in a motored engine. New techniques show that the motored engine is an accurate tool for combustion studies since end-gas reactions can be simulated without the complication of flame in the cylinder.

Water Injection in Internal Combustion Engines. Aarne Lakomaa. *Saab Sonics*, No. 11, July–September,1950, pp. 5–8, illus. Explanation of the process, the problems involved, and practical advantages.

Disconnect Makes Flights Safer. Scott Reiniger. *Aviation Week*, Vol. 53, No. 17, October 23, 1950, pp. 40, 44, illus. The Stratos model D-3 solenoid-operated engine accessory disconnect by which a failing alternator or generator is disconnected from the engine. This device will be installed on P.A.A.'s Stratocruisers.

Correspondence on "Elementary Aspects of Technical Statistics." John D. North, S. B. Bailey, H. C. Beirs, and E. Rossow. **Author's Reply.** W. E. Thornton-Bryar. *Royal Aeronautical Society, Journal*, Vol. 54, No. 478, October, 1950, pp. 660–668, illus.

Texaco Combustion Process Gives Knock-Free Operation. E. M. Barber, Blake Reynolds, and W. T. Tierney. *SAE Journal*, Vol. 58, No. 9, September, 1950, pp. 51–57, illus. (Excerpts from a paper: The Elimination of Combustion Knock—Texaco Combustion Process.)

Recent Developments in the (Pratt & Whitney) R-4360 Engine. Earle A. Ryder. *SAE Quarterly Transactions*, Vol. 4, No. 4, October, 1950, pp. 559–570, illus.

ROCKET (4)

Stability of Flow in a Rocket Motor. D. F. Gunder and D. R. Friant. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 327–333, illus. 7 references.

Analytical study of the proper design criteria for liquid rocket motors to prevent chugging. Several methods of solution are worked out for monopropellant rockets. The method of Nyquist, which involves a conformal transformation, appears to be the most satisfactory. The solution is extended to cover the bipropellant system. The solution with the Nyquist method is applied to a specific example, and the resulting diagrams show the curve pattern conditions of stability and instability.

Britain Unveils Rocket Motor. *Aviation Week*, Vol. 53, No. 15, October 9, 1950, p. 30, illus.

The "Beta" rocket motor, built by Fairey Aviation Ltd., uses hydrogen peroxide as the oxidizer for the fuel. It has two cylinders, arranged one above the other. The upper cylinder handles pitch control; the lower handles yaw control. The motor has already been flown in an experimental aircraft.

The Vapor Pressure of Liquid Nitrogen. Abraham Solomon Friedman and David White. *American Chemical Society, Journal*, Vol. 72, No. 9, September, 1950, pp. 3931, 3932, illus. 10 references.

Production (36)

Efficiencies in Aircraft Production. T. E. (Eric) Springer. *Automotive Industries*, Vol. 103, No. 8, October 15, 1950, pp. 34–37, 108, 110, illus. Planning techniques at Douglas Aircraft Co., Inc.

Production Engineering, Administration and Management. VI. J. V. Connolly. *Aircraft Engineering*, Vol. 22, No. 260, October, 1950, pp. 304–307, illus. 20 references.

Goods Inwards and Despatch: "On-Wheels" System to Simplify Receiving and Shipping Problems at Douglas Aircraft. K. R. Benfield. *Aircraft Production*, Vol. 12, No. 143–144, September-October, 1950, pp. 270, 271, illus.

The S.B.A.C. Show: Some Notes on Production Equipment, Materials, and Other Products Displayed at Farnborough in This Year's Static Exhibition. *Aircraft Production*, Vol. 12, No. 143–144, September-October, 1950, pp. 282–288, illus.

Teamwork—A Must for Aero Standardization. J. H. Sidebottom and G. N. Cole. *SAE Journal*, Vol. 58, No. 9, September, 1950, pp. 73–76, illus. (Excerpts from a paper.)

Subcontractor's Package. William S. Friedman. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 45, 97–99, illus.

A practical method of industrial mobilization planning setup by Fairchild Engine and Airplane Corp. for expanding production of the C-119 Packet. The "subcontractor's package" is a mass of production information, systematically arranged, which tells the subcontractor exactly what has to be done and how to do it to achieve a uniform result.

Airspeed Ambassador. III—Front- and Rear-Fuselage Subassemblies; Main Fuselage Assembly and Fixture-Design; Skin-Plating Sequence. S. C. Poulsen. *Aircraft Production*, Vol. 12, No. 143–144, September-October, 1950, pp. 272–278, illus.

An Inexpensive Cutting Tool; A New Method of Blanking Development by the Boeing Airplane Company. E. Carpenter. *Aircraft Engineering*, Vol. 22, No. 260, October, 1950, p. 309, illus.

A steel cutting rule, or "dinking die," cuts through aluminum and stainless steel, resulting in greater accuracy and simplified setups.

Joining Nimonic: The Wiggin Series of High-Nickel Alloys; Procedure Recommended for Soldering, Brazing and Welding. *Aircraft Production*, Vol. 12, No. 143–144, September-October, 1950, pp. 265–269, illus.

Bent Structural Members. II—Heat Treatment and Strength Values of Aluminum-Alloy Materials; Incidence of Sheet-Forming Operations. R. M. Howarth. *Aircraft Production*, Vol. 12, No. 143-144, September-October, 1950, pp 294–296, illus. 1 reference.

Hot-Dimpling: Process for High-Strength Light-Alloy Sheet Developed by Short Brothers and Harland, Ltd. *Aircraft Production*, Vol. 12, No. 143–144, September-October, 1950, pp. 289–291, illus.

Aluminium-Sheet Production: Opening of the Northern Aluminium Company's Continuous Strip-Rolling Mill at Rogerstone. *Aircraft Production*, Vol. 12, No. 143–144, September-October, 1950, p. 279, illus.

Joggling: North American Practice in Manipulating Extrusions and Formed-Sheet Sections. *Aircraft Production*, Vol. 12, No. 143–144, September-October, 1950, pp. 280, 281, illus.

A Survey of Aluminum Welding Techniques. Floyd A. Lewis. *Tool Engineer*, Vol. 25, No. 4, October, 1950, pp. 21–23, illus.

Boosting Production with Outriggers. M. D. McNaughton. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 44, 45, 106, illus.

Use of an Airfeedrill (an air-powered outrigger) makes possible two complete drilling operations in a single setup. This outrigger is easily attached and needs no complex mounting.

Propellers (11)

Theory and Use of the Supersonic Airscrew. W. F. Hilton. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2345*, 1950 (August, 1946). 10 pp., illus. British Information Services, New York. $0.50.

Development of the exact theory of an entirely supersonic propeller moving at a supersonic forward velocity. Ackeret's linear airfoil theory is used to derive an expression for the propeller's performance. Blade efficiency is of the order of 70 per cent. For maintaining supersonic speeds along the propeller blade, a large spinner with a number of short blades should be operated at a higher rotational speed than for subsonic propellers. The theory was worked out for tip speeds $> M = 1.5$, neglecting interference effects.

Design and Operation of Gas Turbine Propellers. R. C. Treseder and D. D. Bowe. *S.A.E., National Aeronautic Meeting, Los Angeles, September 28–30, 1950, Preprint No. 514.* 14 pp., illus.

Outline of the propeller design procedure for a given type of turboprop installation, covering the aerodynamic, mechanical, and control aspects of the problem. The propeller considered is the aeroproducts dual-rotation propeller used on the Douglas XA2D airplane. It is basically two independent hydraulic propellers connected by a mechanical coupling that adjusts the blade angle of the outboard propeller according to the dictates of the inboard. The requirements of high power absorption without greatly increased propeller diameter favor the dual-rotation propeller. An electronic control system regulates the pitch of the blades. Test experience on the installation is summarized, and the propeller operating characteristics are given in graphs.

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Why We Still Need the Propeller. Ivan H. Driggs. *Aviation Week*, Vol. 53, No. 17, October 23, 1950, pp. 28–30, 33, illus.

Analysis of turboprop and turbojet propulsion factors. Equations are obtained for the propulsive efficiencies of both systems and the two systems are compared on the basis of thrust power or power per unit fuel flow.

Reversing Props in Flight Promises Safer Air Travel (Excerpts from a paper: Investigation of Reversing Propeller Pitch on a Multi-Engine Aircraft in Flight.) Herbert O. Fisher. *SAE Journal*, Vol. 58, No. 9, September, 1950, pp. 35–39, illus.

Tomorrow's Props: Very Thin and Fast. Alexander McSurely. *Aviation Week*, Vol. 53, No. 16, October 16, 1950, pp. 18, 21, illus. The Aeroproducts three-bladed small-diameter single-rotation propeller. The very thin blades taper towards the tip; rotational speed is approximately 4,000 r.p.m.

Heat Requirements for Ice Prevention on Gas-Heated Propellers. Vernon H. Gray. *SAE Quarterly Transactions*, Vol. 4, No. 4, October, 1950, pp. 500–506, illus. 9 references.

Determination of the requirements by analyzing wet-air phenomena. Rates of heated-gas flow which provide sufficient surface heating of the blades are not large enough to give complete ice prevention at the leading edge. Experimental results indicate a method of accurately predicting heat requirements for a specific set of conditions.

Research Facilities (50)

The Role of Research in Aircraft Development. Hugh L. Dryden. *National Air Review*, Vol. 2, No. 2, October, 1950, pp. 11–15.

Rotating Wing Aircraft (34)

Some Notes on the Flapping Motion of Rotor Blades. J. B. B. Owen. *Gt. Brit., Aeronautical Research Council, Current Papers No. 1*, 1950 (December, 1947). 18 pp., illus. 6 references. British Information Services, New York. $0.50.

Expressions for the causes of instability in the flapping movements are derived by considering the stability of the flapping motion at any fixed azimuth. A value is calculated for the tip-speed ratio at which flapping instability will first appear, assuming a uniform blade that is rigid in bending but flexible in torsion. Stability can be appreciably increased by decreasing the pitch as the blades flap. Derivation of the flapping motion equations, the effect of pitch change in flapping, and the effect of offset between inertia and flexural axes are reviewed. Calculation processes now available should be used for further studies of the flapping equations.

Theory of Helicopter Damping in Pitch or Roll and a Comparison with Flight Measurements. Kenneth B. Amer. *U.S., N.A.C.A., Technical Note No. 2136*, October, 1950. 25 pp., illus. 6 references.

The Development of Jet Helicopters in France. André Charriou. *Aircraft Engineering*, Vol. 22, No. 260, October, 1950, pp. 292–295, illus.

A modification of the Doblhoff (pressure jet) system is used in these helicopters developed by S.N.C.A.S.O. The air compressor, operated from either a reciprocating or gas-turbine engine, is installed in the fuselage. Air from this compressor is delivered through the hub and blades to combustion chambers at the rotor tips; fuel is injected into the combustion chamber as a liquid. Two prototype machines have been built, and a third type is under construction.

Helicopter Studies in France. R. M. Garry. *Aero Digest*, Vol. 61, No. 4, October, 1950, pp. 38, 39, 91–94, illus. Specifications and performance of French prototype helicopters, incuding reciprocating-engined and jet-powered types.

Seibel Copter (S-4) Stresses Simplicity. *Aviation Week*, Vol. 53, No. 17, October 23, 1950, pp. 25, 27, illus.

Sciences, General (33)

CHEMISTRY

The Separation of the Rotational Coordinates from the N-Particle Schroedinger Equation. C. F. Curtiss, J. O. Hirshfelder, and F. T. Adler. *Wisconsin, University, Naval Research Laboratory, Report No. CM-621 (NOrd 9938)*, July 20, 1950. 15 pp., illus. 3 references.

MATHEMATICS

Soap-Film and Sandbed-Mapper Techniques. A. D. Moore. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 291–298, illus. 3 references.

The torsional stresses in a shaft of arbitrary cross section can be investigated by the soap-film method. If a slightly inflated soap film is formed on a plane base (the film boundary being identical with the shaft boundary), contour lines on the soap film correspond to lines of maximum shear. A photograph is taken of a spider-web grid reflected on the soap film and is analyzed for contour lines and lines of maximum slope. There is a definite similarity between a fluid mapper of the isolated sandbed type and soap-film mapper. Both these means seem to be analogous to other noncircular two-dimensional distributed-source situations. Sandbed-pattern analysis appears to be simpler than soap-film analysis.

A Mechanical Analyzer for Computing Transient Stresses in Airplane Structures. R. L. Bisplinghoff, T. H. H. Pian, and L. I. Levy. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 310–314, illus. 6 references.

Determination of transient stresses in an undamped elastic structure through the use of a mechanical-analogy-type analyzer. The analyzer is based on an adaptation of the fundamental principles of the torsional-pendulum simulator devised by Biot, but it has been extended to solve problems involving several deformation modes. The analyzer evaluates the stresses due to the deformation of an elastic structure in its various normal modes by use of the torsional-pendulum simulator. The effects of the modes with due regard to their phase relations are added to the stresses by the electronic pickup and recording circuits. Computation of the bending moment at the wing root of a 23,000-lb. seaplane during landing with the use of the analyzer gave results that were less than 3 per cent different from those calculated by the most exact methods.

A Study of the Response of an Airplane Landing Gear Using the Differential Analyzer. Walter C. Hurty. *Journal of the Aeronautical Sciences*, Vol. 17, No. 12, December, 1950, pp. 756–764, illus. 6 references.

The NBS Computer Program. *U.S., National Bureau of Standards, Technical News Bulletin*, Vol. 34, No. 9, September, 1950, pp. 128, 129, illus.

SEAC, The National Bureau of Standards Eastern (Binary) Computer. *U.S., National Bureau of Standards, Technical News Bulletin*, Vol. 34, No. 9, September, 1950, pp. 121–125, illus.

SEAC's Solution of a Heat-Flow Problem. *U.S., National Bureau of Standards, Technical News Bulletin*, Vol. 34, No. 9, September, 1950, pp. 126, 127, illus.

Numerical Determination of Characteristic Numbers. W. E. Milne. *U.S., National Bureau of Standards, Journal of Research*, Vol. 45, No. 3, September, 1950, pp. 245–254. (Also available as *Research Paper No. 2132*. U.S. Govt. Printing Office, Washington. $0.10.) Method for obtaining the latent roots of a matrix.

The Statistics of Correlated Events. I. C. Domb. *Philosophical Magazine*, Vol. 41, No. 321, October, 1950, pp. 969–982. 9 references.

Transients in Multiply Periodic Non-Linear Systems. Frank E. Bothwell. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 247–254, illus. 2 references.

Pseudo Closed Trajectories in the Family of Trajectories Defined by a System of Differential Equations. L. A. MacColl. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 255–263, illus.

MECHANICS—VIBRATION

Periodic Motions of a Non-Linear Dynamic System. H. Serbin. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 296–303. 3 references.

Analysis of the problem of the one-dimensional motion of a particle of unit mass suspended on a spring of unit stiffness and subject to negative damping at low amplitudes and positive damping at high amplitudes. The periodicity of the solution exists for a wide range of differential equations in which no symmetry of $f(x)$ and $g(x)$ is required. Inequalities relating to the initial energy and amplitude of the motion are derived which provide a basis for obtaining the upper and lower bounds of periodic motion without solving the differential equation. The graphic methods by which these nonlinear inequalities are solved are not analogous to the graphical methods of solution of the differential equation. Several periodic solutions are shown to exist. A set of inequalities is given for obtaining the numerical bounds to the amplitude of recurrent motion.

Space Travel

Space Rocket Trajectories. Samuel Herrick. *British Interplanetary Society, Journal*, Vol. 9, No. 5, September, 1950, pp. 235–241, illus. 1 reference.

The "variation of constants" method is applied to the timing and direction of a space rocket during take-off. The formulas derived are used to estimate the velocity necessary to carry an interplanetary rocket to its destination.

Note on a Paper by G. F. Forbes. Derek F. Lawden. *British Interplanetary Society, Journal*, Vol. 9, No. 5, September, 1950, pp. 230–234. 3 references.

Forbes' paper, "The Trajectory of a Powered Rocket in Space," is a mathematical investigation of the methods of transfer between circular orbits. This note develops the argument that transfer by way of tangential eclipse represents the best, but not necessarily the most convenient, method.

Structures (7)

A Mechanical Analyzer for Computing Transient Stresses in Airplane Structures. R. L. Bisplinghoff, T. H. H. Pian, and L. I. Levy. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 310–314, illus. 6 references.

Determination of transient stresses in an undamped elastic structure through the use of a mechanical-analogy-type analyzer. The analyzer is based on an adaptation of the fundamental principles of the torsional-pendulum simulator devised by Biot, but it has been extended to solve problems involving several deformation modes. The analyzer evaluates the stresses due to the deformation of an elastic structure in its various normal modes by use of the torsional-pendulum simulator. The effects of the modes with due regard to their phase relations are added to the stresses by the electronic pickup and recording circuits. Computation of the bending moment at the wing root of a 23,000-lb. seaplane during landing with the use of the analyzer gave results that were less than 3 per cent different from those calculated by the most exact methods.

A Method for Determining Mode Shapes and Frequencies Above the Fundamental by Matrix Iteration. H. I. Flomenhoft. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 249–256, illus. 5 references.

This technique, based on a device worked out by L. A. Pipes, is a mode-by-mode process in which the constants obtained as a final result of one mode are used together with the new orthogonality condition to find the constants for the next mode. General formulas are determined for constants of the sweeping matrix for eliminating the first modes in a system with n degrees of freedom, and a checking method is derived for the sweeping operation. Tables for finding sweeping constants for the first five modes with five degrees of freedom are adapted for sweeping columns to zero successively from left to right. A numerical example of a 14-degree of-freedom system of a full-size airplane wing illustrated how the tables are used when the columns must be swept in irregular fashion.

Matrix Solution for the Vibration of Nonuniform Beams. W. T. Thomson. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 337–339, illus. 3 references.

The matrix solution for the natural frequencies gives results analogous to those obtained with Myklestad's tabular method, but the matrix computation process is much simpler. The matrix equation obtained holds for any boundary conditions. The solutions are given for the boundary conditions of a cantilever beam, a beam with hinged ends, and an airplane wing. The solution is carried out for the case of a nonuniform beam represented by a series of uniform sections.

Elastic-Plastic Analysis of Structures Subjected to Loads Varying Arbitrarily Between Prescribed Limits. P. S. Symonds and W. Prager. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 315–323, illus. 20 references.

A new approach to the general problem of determining if a structure can safely carry a set of external loads whose maximum and minimum values only are known. The basic structure considered is a statically indeterminate plane truss, with loads applied at the joints, with each bar in simple torsion or compression. An

instantaneous state of stress is set up in an appropriate "stress space," with the forces represented geometrically. The usual rules of vector algebra and geometry are used to determine the forces. This method, with appropriate changes in terminology, can be extended to cover other structures and even continuous media.

Flutter and Divergence of Sweptback and Sweptforward Wings. A. W. Babister. *College of Aeronautics, Cranfield, England, Report No. 39,* June, 1950, 18 pp., illus. 3 references.

The equations of the displacement in flexure and torsion of a semirigid, straight, tapered wing in both compressible and incompressible flow. For highly sweptback or sweptforward wings, the flutter speed is double that for unswept wings with the same wing stiffness. The critical flutter speed increases rapidly as the inertia axis is moved forward. For highly sweptforward wings, wing divergence is almost independent of the torsional stiffness, and it occurs before flutter. For unswept wings, it is independent of the flexural stiffness. The critical flutter speed is, in general, higher for sweptback wings.

Note on Frazer's Proposed Method for the Numerical Solution of Flutter and Stability Problems. H. L. Price. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2393,* 1950 (August 14, 1944). 8 pp. 1 reference. British Information Services, New York. $0.50.

Simplified method of solution of the two simultaneous equations derived by Frazer for obtaining the corresponding sets of values of critical speed and critical frequency. Curves of these functions are plotted by an arithmetical process involving factorial expressions if a framework is used in which complete algebraic symmetry exists between any two lines of the framework. The entire series of values may be determined without the use of the system of double-entry tables recommended by Frazer.

Readers' Forum: Determination of Deflections in Redundant Structures. H. L. Cox and D. G. Sopwith. *Journal of the Aeronautical Sciences,* Vol. 17, No. 12, December, 1950, p. 815.

Analytical and Experimental Studies on Dynamic Loads in Airplane Structures During Landing. T. H. H. Pian and H. I. Flomenhoft. *Journal of the Aeronautical Sciences,* Vol. 17, No. 12, December, 1950, pp. 765–774, 786, illus. 10 references.

Bending of an Elliptical Plate by Edge Loading. W. A. Nash. *Journal of Applied Mechanics,* Vol. 17, No. 3, September, 1950, pp. 269–274, illus. 9 references.

Series solution (with all functions and solutions expressed in elliptical coordinates) for the problem of small deflections of a thin elliptical plate the edge of which is supported and given a small deflection perpendicular to the middle line of the plate. Since the external load consists only of bending moments around the edge of the plate, the solution reduces to a biharmonic equation satisfied by two functions. Solution of a biharmonic function that is not harmonic is obtained through the use of complex variables. The biharmonic function that is harmonic can be determined by the method of separation of variables in Laplace's equation. The series converges absolutely and uniformly in both variables throughout the entire plate, including the boundary.

On the Buckling of a Rectangular Plate Uniformly Compressed in One Direction and Having Various Edge Conditions. Masao Naruoka. *Japan Society for Applied Mechanics, Journal,* Vol. 3, No. 17, May, 1950, pp. 97–103, illus. 4 references. In Japanese.

A rapid method of calculating the buckling force of a rectangular plate uniformly compressed and having various edge conditions (four edges clamped; three edges clamped, the other simply supported; two adjoining edges clamped, the other simply supported; etc.) was derived by using two moment-slope coefficients introduced by the author.

Finite Difference Equations for the Analysis of Thin Rectangular Plates with Combinations of Fixed and Free Edges. M. V. Barton. *Texas, University, Defense Research Laboratory, Report No. CF-1005 DRL-175,* August 6, 1948. 26 pp., illus. 7 references.

Vibration of Rectangular and Skew Cantilever Plates Representing Idealized Missile Fins. M. V. Barton. *Texas, University, Defense Research Laboratory, Report No. CM-570 DRL-222,* December 14, 1949. 41 pp., illus. 13 references.

Natural frequencies and modes are calculated by the Ritz method for rectangular cantilever plates with span to breadth ratios of $^1/_2$, 1, 2, and 5 and for skew cantilever plates with sides of equal length and skew angles of 15°, 30°, and 45°. The functions used are combinations of the characteristic functions that define the normal modes of vibration of a uniform beam with one end fixed and for a uniform beam with both ends free. Test results show good correlation with analytical results.

The Approximate Deflection of Thin Flat Triangular Cantilever Plates Subjected to Uniform Normal Load. F. S. Shaw. *Australia, Department of Supply, Aeronautical Research Laboratories, Report No. SM. 154,* June, 1950. 22 pp., illus. 3 references.

Approximate solutions for the deflection are obtained by the Ritz procedure for a function that satisfies the prescribed kinematic (but not the static) boundary conditions. A specific numerical example is worked out in detail, giving three approximate solutions. An investigation of the accuracy of these solutions indicates that only a fair solution can be obtained with a reasonable amount of computation. Greater accuracy can be obtained by extending the process, but this would involve the solving of 15 simultaneous equations.

Readers' Forum: On the Plastic Buckling of Plates According to the Flow Theory. P. P. Bijlaard. *Journal of the Aeronautical Sciences,* Vol. 17, No. 12, December, 1950, pp. 810, 811, illus. 5 references.

The Uniform Flexure of an Incomplete Tore. W. Freiberger and R. C. T. Smith. *Australian Journal of Scientific Research, Series A, Physical Sciences,* Vol. 2, No. 4, December, 1949, pp. 469–482, illus. 10 references.

The deformation by flexural couple of a bar curved into the form of a circle is examined by a stress-function method. The stress system corresponds to that of a helical spring under axial torsion. A solution originally involving two potential functions and a third function is expressed in terms of two harmonic functions that are subject to the boundary conditions on the circumference which involve the first two derivatives of the functions. The resultant of the stresses that correspond to the displacements over any cross section is the required flexural couple. The solution is related to the general solution of three-dimensional elasticity problems.

Torsion of Noncylindrical Shafts of Circular Cross Section. H. J. Reissner and G. J. Wennagel. *Journal of Applied Mechanics,* Vol. 17, No. 3, September, 1950, pp. 275–282, illus. 8 references.

Investigation of the classes of boundary shapes, displacements, and stress distributions of noncylindrical bodies of revolution for the class of integrals of the form of the product of two functions of axial and radial coordinates. The method is analogous to Saint Venant's semi-inverse method for cylindrical bodies. Results of investigations of the single-term integrals for solid and hollow cross sections are presented numerically and graphically. A detailed analysis of the boundary shapes from the series integrals leads to mathematical complications requiring further study.

Shear Lag in Tension Panels and Box Beams. Manford B. Tate. (Ph.D. Thesis.) *Iowa State College, Iowa Engineering Experiment Station, Engineering Report No. 3,* 1950. 189 pp., illus. 31 references.

Theoretical and experimental study of the stresses in strong longitudinal members and thin web and cover sheets when the panel is subjected to tensile forces and the box beam is used as a cantilever. Conditions before and after failure of the cover sheet due to buckling are considered. This theory does not assume uniform distribution of the stresses across the width of the sheet but includes the computation of the actual stress as part of the problem. In addition to general formulas, expressions for stresses with five common types of leading conditions are fully developed. Experiments were conducted on two flat-cover box beams of the dimensions met in aircraft construction. Stress results checked with the theory herein developed but differed significantly from conventional theories. The maximum stresses were found to be 10–36 per cent higher than those computed by conventional theories. The loads carried in compression by the full cover sheets were found to be 20–45 per cent lower than that predicted by other methods, while the loads in tension were 94 per cent of those determined by conventional theories.

On the Stresses at the Edge of an Eccentrically Located Circular Hole in a Strip Under Tension. Sverker Sjöström. *Sweden, Flygtekniska Försöksanstalt, Stockholm, Meddelande Nr. 36,* 1950. 27 pp., illus. 5 references. Kr. 3:-. In English.

The stresses are expressed by means of an Airy stress function for an infinite plate under unidirectional tension with a circular hole. Determination of an auxiliary stress function by a Fourier integral results in the vanishing of the stresses on the straight edge. This function causes stresses on the edge of the hole to be introduced, which are in turn canceled by another function.

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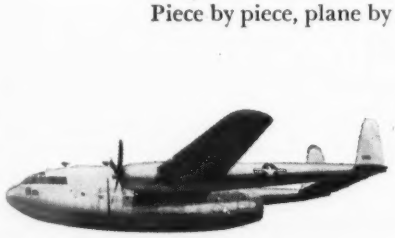

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Stresses become arbitrarily smaller as the process converges. The procedure converges for any hole whose diameter is less than the distance between the plate edge and the center of the hole.

On the Solution of the Equilibrium Equations of Elasticity in General Curvilinear Coordinates. W. Freiberger. *Australian Journal of Scientific Research, Series A, Physical Sciences*, Vol. 2, No. 4, December, 1950, pp. 483–492, illus. 6 references.

A system of stress functions consisting of a harmonic vector and a harmonic scaler potential is introduced into the equations of equilibrium of an isotropic elastic body in arbitrary curvilinear coordinates and tensor form. The components of displacement and of the stress tensor are expressed in terms of these potentials, and it is shown that the total number of independent components of the potentials is reducible to three. The tensor equations are specialized to orthogonal curvilinear coordinates and expressions derived for the "physical" components of displacement and stress in terms of the stress functions. The method is compared with the equations of Galerkin and Papkovitch-Neuber.

On the Atomic Theory of Elasticity. Kun Huang. *Royal Society (London), Proceedings, Series A, Mathematical and Physical Sciences*, Vol. 203, No. 1073, September 22, 1950, pp. 178–194. 14 references.

A general scheme was developed to illustrate the theories of lattice dynamics without specific assumptions concerning atomic interactions. The peculiar difficulties of the scheme are investigated, and a new approach is presented to the discussion of the representation of the complete stresses and of potential energy of a homogeneous deformation of an arbitrary reference configuration. This new technique assumes that only the anisotropic stresses in the reference configuration can be explicitly represented. When the condition that these stresses vanish is introduced, the elastic constants can be determined if the remaining stress vanishes also. The reliability of the method is illustrated for the case where each lattice point is a center of symmetry.

The Dirichlet Problem: Bounds at a Point for the Solution and Its Derivatives. Clair G. Maple. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 213–228, illus. 8 references.

An investigation of the Dirichlet problem in a Euclidian N-space E_N. It is assumed that the solution has already been located on a hypercircle in function space by means of the method of Prager and Synge. A method is derived for determining the bounds for the mean value of the solution at an interior point and for the derivatives of the solution at that point. Bounds are also determined for the normal derivative on a point on a plane face.

Analysis of Stress-Strain-Time Relations from the Engineering Viewpoint. F. R. Shanley. *The RAND Corporation, Report No. P-68*, March 4, 1949. 39 pp., illus. 27 references.

Development of stress-strain diagrams for various loading histories by a step-by-step process in which elastic action is assumed to be instantaneous and reversible. Plastic action is assumed to occur at constant stress as a function of stress, time, and the extent of plastic straining. The plastic flow curves are shown to be the correct basis for analyzing stress-strain-time relationships that are affected by loading rate, temperature, and combined stress conditions. Shearing stresses have no effect on elastic action. The use of the octahedral shearing stress as a basis for the theory of stress-strain relationships appears to be questionable; the actual planes of slip under various conditions of combined loading should be determined. A few practical examples illustrate the engineering applications of the theory.

The Influence of Stress on Corrosion. II. Julius J. Harwood. *Corrosion*, Vol. 6, No. 9, September, 1950, pp. 290–307, illus. 40 references.

Thermoelastic Stress Around a Cylindrical Inclusion of Elliptic Cross Section. Raymond D. Mindlin and Hilda L. Cooper. *Journal of Applied Mechanics*, Vol. 17, No. 3, September, 1950, pp. 265–268, illus. 8 references.

The two-dimensional equations of thermoelasticity are solved for the case of a uniform temperature change of an infinite medium containing a cylindrical inclusion of elliptic cross section. The problem is treated as one of plane strain in elliptic coordinates, and the solution is given in closed form. Formulas and curves show the maximum values of various components of stress at the interface between the inclusion and the surrounding medium.

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Quenching Stresses in Transparent Isotropic Media and the Photoelastic Method. R. C. O'Rourke and A. W. Saenz. *Quarterly of Applied Mathematics*, Vol. 8, No. 3, October, 1950, pp. 303–311, illus. 6 references.

Development of a mathematical theory of residual stresses based on a simple model of the quenching process and using a careful reinterpretation of the classical theory of thermal stresses. The process reduces to the inversion of Abel's integral equation; in the cylinder the residual stresses are assumed to be elastic. Derivation of exact methods for showing the elastic nature of these residual stresses justifies this assumption. Formulas are derived which indicate the applicability of the photoelastic method to the study of quenching stresses. The results of this process are useful in locating exposed tension regions in quenched cylinders and spheres and in obtaining rough ideas of the residual stresses in nontransparent polycrystalline materials.

Thermodynamics (18)

Heat Transfer, Mass Transfer, and Fluid Friction Relationships in Turbulent Flow. Thomas K. Sherwood. *Industrial and Engineering Chemistry*, Vol. 42, No. 10, October, 1950, pp. 2077–2084, illus. 24 references.

An outline of the theory and experimental data relating the three interphase transfer processes; and a review of the nature of fluid flow in pipes and the concepts of molecular diffusion, turbulence, and eddy diffusion. The theory is applied to the overall process of transfer between the wall of a pipe and the turbulent fluid flowing through the pipe. A comparison of the representative data on the three processes illustrates their basic similarity and the simplicity of the relationships between them.

Water-Borne Aircraft (21)

Hydrodynamic Properties of Planing Surfaces and Flying Boats. N. A. Sokolov. (*Tsentral'nyi Aero-Gidrodinamicheskii Institut, Leningrad, Trudy No. 149*, 1932, pp. 1–39.) *U.S., N.A.C.A., Technical Memorandum No. 1246*, October, 1950. 58 pp., illus. 2 references.

Short Flight-Test Development. S. G. Marshall. *Flight*, Vol. 58, No. 2180, October 5, 1950, pp. 374–376, illus. Refinements in design and construction in the Short Sealand and Short Sturgeon which resulted from an extensive flight test program.

Development of the Princess, The Building of the Aircraft. E. Goodenough. *New Slipway* (*Saunders-Roe Ltd.*), Vol. 1, No. 6, October, 1950, pp. 2–5, illus.

Lateral Deformation of a Ship of Uniform Skin Floating on Water; A Suggested Method of Solving an Integral Equation. Seinen Yokota. *Japan Society for Applied Mechanics, Journal*, Vol. 3, No. 17, May, 1950, pp. 104–107, illus. In English.

The problem is one of the elasticity of a ship under water pressure and with forces and couples at the end. The ship is of arbitrary cross section and without supporting members. The equation of equilibrium is developed for the cross section before the stress is applied. This equation can be solved by developing the unknown function in a power series according to Taylor's theorem. The solution reduces to one equation of absolute terms with an unknown moment M. The integrals are derived for the corrections due to supporting beams or pillars in the cross section.

Water Stability Tests on Saro 37 Fitted with Shetland Hul Bottom Wing Tip Floats and Tail. I. W. McCaig. *Gt. Brit. Aeronautical Research Council, Current Papers No. 3*, 1950. 16 pp., illus. 1 reference. British Information Services, New York. $0.35.

Investigations to determine the water-stability limits over a range of weights and c.g. positions. The change from the S.37 to the Shetland-type tail has little or no effects on the stability limits, but the Shetland tail is more effective at take-off and gives a higher attitude over the hump. Altitude, acceleration, and elevator angle during take-off and landing were plotted against water speed to obtain the stability limits. In water tests, handling was satisfactory with c.g. normal at 120,000 lbs. weight; with c.g. forward it was difficult to avoid lower limit porpoising; with c.g. aft, there was a tendency to bounce. Moving the c.g. forward lowers the trim and upper limit while the lower limit and the bounce porpoising limit remain almost unchanged. Moving the c.g. aft raises both the upper limit and trim; the lower limit is unchanged.

Wind Tunnels (17)

Note on the Interference on a Part-Wing Mounted Symmetrically on One Wall of a Wind-Tunnel of Octagonal Section. H. C. Garner. *Gt. Brit., Aeronautical Research Council, Current Papers No. 5*, 1950 (March 6, 1947). 28 pp., illus. 5 references. British Information Services, New York. $0.65.

Method of determining the interference in an octagonal wind tunnel in the form of an upwash angle at any point on the plan form of a part-wing due to a system of images (combination of horseshoe vortices) corresponding to any given lift distribution. Two factors in the upwash velocity are considered: the velocity induced at points along the line of the bound vortex, and the velocity variation in the direction of the undisturbed stream. The calculations for the interference in the N.P.L. 9- by 7-ft. tunnel are tabulated. The chordwise variation of the upwash angle is practically linear; the total upwash angle along any chord may be represented as a local uniform incidence added to a superposed curvature of flow. The octagonal tunnel produces more upwash than a rectangular tunnel near the wall where the part-wing is mounted. The interference is appreciable in the root-section of the wing being examined.

Problems in Shock Reflection. *California Institute of Technology, Guggenheim Aeronautical Laboratory, Contract No. W33-038 ac-1717 (11592), Final Report*, 1949. 55 pp., illus. 9 references.

Experimental studies on the reflection of shock waves from boundary layers. Preliminary work showed that the GALCIT 2- by 20-in. transonic wind tunnel would have to be modified to obtain adequate results in shock reflection tests. The dimensions of the test section were changed to 4- by 10-in., and the length was increased from 36 in. to 48 in. The new test section is equipped with a flexible nozzle, and traversing equipment has been installed. Test-section Mach Numbers range from 1.10 to 1.50. A second flexible nozzle section at the diffuser entrance acts as a second throat during supersonic operation and as a speed control during subsonic operation. A qualitative analysis of the propagation of a weak wave in a rectilinear supersonic stream where the Mach Number of the undisturbed stream varies only from streamline to streamline is presented for the cases where the waves are sufficiently weak to permit use of the linearized "Mach wave" concept. Mathematical expressions were derived for the transmission-reflection phenomenon in general.

University of Michigan 8 × 13 Inch Intermittent-Flow Supersonic Wind Tunnel. L. C. Garby and W. C. Nelson. *Michigan, University, Aeronautical Research Center, External Memorandum No. UMM-59*, June, 1950, 31 pp., illus. 3 references.

A vacuum-type wind tunnel that establishes operating potential by evacuating a 13,000-cu. ft. vacuum tank and utilizing the pressure differential between the atmospheric air storage bag and the tank to set up supersonic flow in the test section. The tunnel is of closed-circuit design to facilitate air drying and cleaning.

The Development and Performance of Two Small Tunnels Capable of Intermittent Operation at Mach Numbers Between 0.4 and 4.0. Walter F. Lindsey and William L. Chew. *U.S., N.A.C.A., Technical Note No. 2189*, September, 1950. 105 pp., illus. 27 references.

N.A.C.A.'s Hypersonic Wind Tunnels. Gilbert C. Close. *Aviation Age*, Vol. 14, No. 4, October, 1950, pp. 32, 33, illus.

Supersonic Research. Smith J. DeFrance. *The Pegasus*, Vol. 16, No. 3, September, 1950, pp. 1–5, illus. The 10- by 14-in. supersonic wind tunnel and the supersonic free-flight wind tunnel at N.A.C.A. Ames Aeronautical Laboratory for research at speeds up to Mach 7.

The Automobile . . . Moving People Through Air; Aerodynamic Characteristics of American Passenger Cars. L. H. Nagler and Kenneth Razak. *SAE Quarterly Transactions*, Vol. 4, No. 4, October, 1950, pp. 530–541, Discussion, 541–545, illus. 8 references.

Experiments on the air drag of 11 American automobiles in a wind tunnel; description of the 7- by 10-ft. single-return, closed-throat wind tunnel at the University of Wichita.

Research in Supersonics at Princeton University. S. M. Bogdonoff. *Instrumentation*, Vol. 4, No. 6, 1950, pp. 26–28, illus

Design and operation of the 4- by 8-in. variable-density supersonic blow-down wind tunnel at Princeton University which can simulate full-scale flight at Mach Numbers of 1.5 to 5.0, and altitudes from sea level to 80,000 ft.

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Aeronautical Reviews — BOOKS

Introduction to the Transfer of Heat and Mass

By E. R. G. Eckert. New York, McGraw-Hill Book Company, Inc., 1950. 284 pp., illus., tables, diagrs. $4.00.

The phrase "Introduction to" usually connotes coverage of basic physical processes and laws together with a presentation of existing fundamental knowledge. However, there are sections of E. R. G. Eckert's revision of his original German text where this scope is far exceeded. By providing a different method of attack for convection problems, *The Transfer of Heat and Mass* will open new vistas to the mechanical, aeronautical, and chemical engineers concerned with heat transfer.

The author, an experimental engineer and scientist with the Air Materiel Command at Wright Field and a consultant to the N.A.C.A., is actively engaged in heat-transfer work, especially in the field and techniques of interferometric studies. Fortunately, he has included many results of his own researches.

Of the four main subdivisions of the book, two—those dealing with heat transfer by convection and transfer of mass—are outstanding; as a matter of fact, almost two-thirds of the text is devoted to the former. Because of the unusual, although thoroughly worthwhile, preponderance of convection data, coupled with its unique manner of presentation, the work is not ideally suited as a standard classroom text. Nevertheless, its excellence as a reference for a graduate course in heat transfer cannot be questioned.

Departing from the usual scheme of separate consideration of particular problems in forced-convection heat transfer, Eckert prefers the broad approach afforded by boundary-layer theory and argues that most of the conductive heat transfer occurs in this layer. The convective section is primarily interested in the study of incompressible fluids and applies the von Kármán-Pohlhausen method of solution. The justification for the use of approximate theory is the good agreement with experimental results or exact solutions. Such calculations provide mathematical simplicity and are possible in many cases where exact solutions are not as yet known.

It is interesting to note that the profiles selected by the author are of either cubic or quadratic form, rather than the traditional quartic of the Pohlhausen method. Whereas the end results—i.e., the skin friction and heat transferred—may compare favorably to known values, they are relatively insensitive to the form of profile chosen. Thus, Eckert fails to point out that the calculated temperature and velocity distributions may be far from accurate.

Because of the aerodynamicist's renewed interest in the laminar boundary layer, it receives intensive study. The analysis of turbulent heat exchange is based on Reynold's analogy and its extension by Prandtl, G. I. Taylor, and von Kármán, wherein the concepts of the laminar sublayer and buffer layer are introduced. Heat transfer in high-speed gas-dynamic flow is treated summarily, no mention being made of the monumental works of Crocco, Brainerd, and Emmons, and von Kármán and Tsien along these lines.

A salient feature of this discussion is the extremely coherent manner in which Eckert demonstrates how nicely theoretical results can lead to empiricisms and similarity cases. The text is replete with these relations, reinforced by corresponding experimental curves and data. While no student problems appear, illustrative examples are generously distributed.

The treatment of the conduction and radiation sections is for the most part routine and naturally cannot be compared to the definitive work of Jacob. Simple unsteady-state theory is covered, and, in this respect, the paragraphs on regenerator calculations by Hausen's method cannot be found elsewhere. As is the case throughout the text, plane surfaces, tubes, and circular cylinders are the basic configurations investigated.

Although the final section presents the laws of mass transfer only for the exchange of water vapor between air and bounding surfaces, it forms an excellent basis for advanced reading. In keeping with the previous chapters, it introduces the idea of a mass-transfer boundary layer, showing the analogy to a heat-transfer process where the heat is transported by conduction through the thermal boundary layer and outside it by convection. Here again, the *modus operandi* represents an innovation.

Even though the subject matter is not treated exhaustively, a complete bibliography indicates the source of all theory. Unfortunately, many of the references are to untranslated German articles that are difficult to procure.

In addition, a large appendix of property values, compiled by Robert M. Drake, Jr., is included, but no indication of how these values were found is given.

The clarity of notation and language, combined with the simplicity of approach, makes *The Transfer of Heat and Mass* a welcome addition to the literature. Indeed, because of the inclusion of the boundary-layer analysis, it is a successful complement to present knowledge.

DR. ROBERT F. BRODSKY
Scandia Corporation

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Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

Ailes Naturelles et Vol Humain (Natural Wings and Human Flight)

By Émile Mollard. With an Introduction by M. R. Thiry. Paris, F.-Louis Vivien, 1950. 58 pp., diagrs. 335 fr.

Into this short work M. Mollard has condensed three books. The first is a simple, though comprehensive, treatment of the general problems encountered in the search for an understanding of natural flight. The second is a careful, detailed approach to further knowledge, based upon a logical speculation. The third is a suggested method of testing this logic by what might be called the synthetic approach.

In a noteworthy introduction, M. Thiry explains the personal interest that the work inspired. He stresses the value of the simplicity, enthusiasm, intuition, and thoroughness that Mollard so amply displays in the work. It is pleasant to hear from a person of M. Thiry's standing a word in defense

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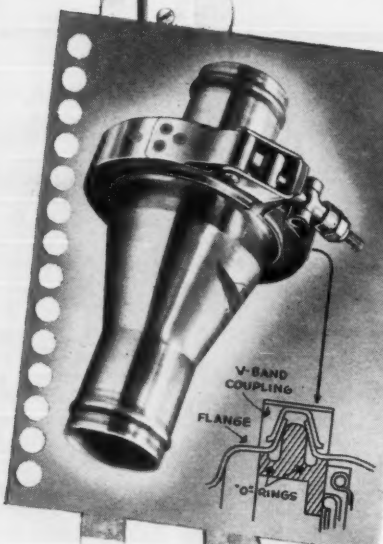

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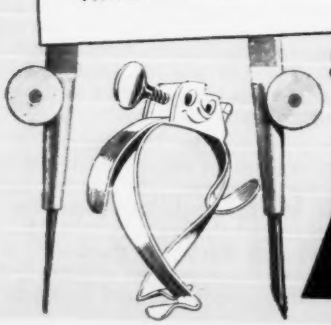

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of qualities like enthusiasm and intuition. Excessive formalism in engineering and scientific papers is all too common. We have been so long tied to the immediate demands of production and so influenced by the scientific philosophy of J. S. Mill that we tend to neglect the role of speculation in scientific advance. Whewell, in his *Philosophy of the Inductive Sciences*, published in 1840, emphasizes the necessary role of such logically constructed organizing ideas.

M. Mollard differs from previous workers in the insect wing theory in two important respects. In the past, thinkers and experimenters have assumed a relatively simple wing. Various airfoil sections, both rigid and nonrigid, have been studied. Their surface has been understood to be smooth and their elasticity subject to uniform flexure. M. Mollard, however, evidently belongs to that school of thought which assumes that until the contrary is proved every detail of a natural organism has a purpose. By acting on this line of thought, it becomes apparent that every structural detail of the wing must be examined.

The first detail so examined is the main frame of the wing. Under microscopic examination the lacy-looking frame would astonish many designers with its rugged appearance. There are three main spanwise beams (nervures). These are interconnected by short interbeam ribs of which only a few are chordwise. The whole structure, connections, and wing covering are elastic. The main beams are not driven simultaneously, according to Mollard.

This latter consideration brings him to an ever-recurring theme in natural-flight studies—namely, the polyphase distribution of mechanical energy in an elastic system. In brief, he treats this energy moving out through these wing beams just as an electrical engineer treats the electrical energy moving in a network problem in alternating current. Its polyphase nature is caused by the lag between the energy impulses to the three wing beams. He points out the general similarity between the bird wing and that of the insect. In doing so, he notes that the trailing edge of the inboard wing panel in the two-winged insect and of the second wing in the four-winged insect is well out of phase with the leading edge. This late arrival of energy gives the same effect as a sudden flap deflection would on a conventional aircraft. Its net effect on a flapping wing would be to help the upstroke while increasing the lift in that period.

His second departure from conventional insect-wing analysis would hardly be startling if the matter had not been so long ignored. It has long been known that the insect wing has a pronounced zig-zag section. The depth of the spanwise channels thus formed is often greater than one-seventh the span. Mollard asks the question, "Why this profile?" He courageously makes the assumption that these channels direct the airflow in a generally

spanwise direction which curves off toward the trailing edge as it approaches the tip. We usually resist suggestions that do not fall in with our past learning. However, a few experiments with a 2-in. diameter steel disc vee grooved at forty-thousandths apart throws interesting light on this suggestion. This disc, when impinged upon by an air jet at a low angle of incidence and rotated through 90°, shows a sharp difference in the intensity and character of the emerging stream. We are no doubt met with another of these little-explored boundary-layer effects. Magnan's smoke-trace studies of the airflow about insect wings throw little light upon the action of these spanwise channels, and we may therefore add them to the ever-growing list of things that demand further study.

The third part of the book, that dealing with the synthetic or constructional method of approach to such problems, is highly to be commended. Few writers or workers in this field have ever published sufficient detail of their work to allow its duplication by other workers. Mollard does here a splendid job comparable with the work of von Holst in Germany and Jordanoglu in Greece. Additive progress in this field obviously depends on this detail. The promise of the method can best be appreciated if we consider what has been done in chemistry and medicine. Here the construction of new compounds and artificial organs not only serves directly but aids also in our understanding of their natural counterparts.

I hope we may have the pleasure of hearing again from M. Mollard as his work progresses.

JAMES L. G. FITZPATRICK
FitzPatrick Company

The Theory and Practice of Industrial Research

By David Bendel Hertz. New York, McGraw-Hill Book Company, Inc., 1950. 385 pp., figs. $5.50.

This book is avowedly devoted to the reduction of well-known and obvious inefficiencies in the area of industrial research. The author believes it to be self-evident that research is susceptible to major improvement by a process of logical planning that will not put undue restrictions upon the creative talents involved. The result is a scholarly tome, which falls short of proving his thesis but which undoubtedly is a valuable tool that can be of great aid to those who are, or expect to be, engaged in the trying occupation of planning and directing industrial research activities.

There are 14 chapters in the book. The first four are devoted to the presentation of the "theoretical, background, and analytical material on creative mentalities, problem solving, and scientific method"—in simpler words, the what and why of research. The remaining ten chapters are confined to the more prosaic aspects of the subject, such as program planning, economics and budgeting, research reports, facilities, patent policies, and internal and public relations. The author suggests that the pragmatic material of the last ten chapters can be useful without the absorption of the philosophical content of the first four. He is probably correct, though he is obviously going to be disappointed if his first four chapters are not studied carefully by his reading public.

Every well-prepared book (and this one is well prepared) reveals a good deal about its origin. To the reviewer, this volume appears to be the most complete, thorough, conscientious, critical review, to date, of the literature on the industrial research process. It is an extremely careful recapitulation and analysis of library material, rather than an exposition of personal experience and individual thought. As such it has a real value but necessarily has certain drawbacks, particularly in the manner of presentation. One detects an air of scholasticism and finds the author unduly erudite, pedantic, and argumentative, even before anyone has started an argument. He is defending a thesis before a critical faculty that actually would not exist if he did not go to the trouble of synthesizing it. This criticism (if that is what it is) is applicable chiefly to the first four chapters, which deal with the philosophy of truth, human thought, and the research function. These chapters consist primarily of references, quotations, and obeisance to authority. They are replete with the special pseudo words of the John Dewey school of philosophy —"suprasensible," "felt difficulty," "insightful." There is a lot of material there that every good researcher really should absorb, but the author has made the absorption unnecessarily difficult. He could have been twice as effective with half as many words—if he had moved well away from the library for a while and then said what he wanted to say in his own way.

Now that the reviewer has dispensed with a possibly pettish reaction to the presentation he should proceed to the more constructive part of his job and tell what is in the book—particularly in the last ten chapters. Though it is unsportsmanlike (the lazy man's approach) he can best do that by listing the chapter titles, which are: The Background of Research in Industry; Research Projects and Programs; The Magnitude of Research Projects and Programs; The Organization and Administration of Research Personnel; Research Economics and Budgeting; Internal Relationships in the Research Group; Formal and Informal Research Reports; Research Facilities—Laboratory Design, Research Tools, and Auxiliary Services; Patent Policies in Research; and External Relationships of the Research Department.

This material is of real value. It is the distilled essence of the best thinking and experience of many people in research planning and mangement, as reported in previous literature. The reviewer found the chapter on Organization and Administration of Research Personnel to be particularly good. Others may find just the answers they are looking for in Research Economics and Budgeting, or perhaps they will be especially interested in the contents of Patent Policies.

It is all worth-while reading, and it should be kept on a handy shelf for reference. The bibliography is extensive, and footnotes and cross references abound. It can serve as a guidepost to extensive collateral reading. The author obviously feels that industrial research can be greatly improved by increased planning and applying of managerial formulas. The reviewer is skeptical as to the extent of possible improvement and believes that many readers will also react that way, but that does not detract from the virtue and value of the basic material. There is no question that the planning for and direction of research organizations can be improved to a considerable degree and that the material in this volume can contribute substantially to such progress.

DR. C. C. FURNAS
Director, Cornell Aeronautical Laboratory, Inc.

Structural Plastics

By H. C. Engel, Charles B. Hemming, and H. R. Merriman. New York, McGraw-Hill Book Company, Inc., 1950. 301 pp., figs. $4.50.

This book is written for the chemists, physicists, structural engineers, designers, and materials engineers who are working with and developing structural plastics. It should assist any of the above by introducing to him the phases of the problem with which he is unfamiliar.

The authors call attention to the tremendous increase in the use of synthetic plastics in the past decade and to the lack of achievement of a sound position for them as materials for load-bearing structures because of inherent structural shortcomings, fabrication difficulties, and general ignorance of their limitations.

Attention is called to progress that has recently been made in developing new materials and fabricating processes to overcome these difficulties. The authors give much valuable information on the composition, design, manufacture, and physical properties of the structural plastics now in use.

The general scope of the book may be judged by the following chapter headings and remarks.

(*1*) *Theoretical Aspects of High-Polymeric Substances.*—This chapter considers the constitution of high polymers, intra- and intermolecular forces, molecular weights, investigation of materials, and the effects of chemical and constitutional characteristics upon the properties of high polymers.

(*2*) *Resins Utilized in Structural Plastics.*—The structure, general behavior, preparation, and properties of

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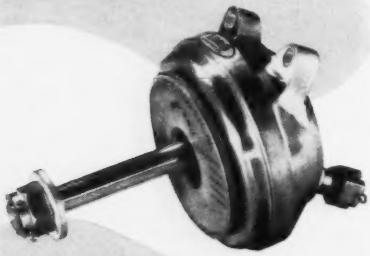

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phenolformaldehyde, urea-formaldehyde, polymerizing-thermosetting, and related resins (the "phenoplasts," "aminoplasts," and "contact" resins) are discussed.

(3) *Reinforcing Materials.*—The structural characteristics of plastic materials are determined partly by the individual properties of the resins or binding materials and, to a greater extent, by the properties of the reinforcing medium. This chapter considers the properties of the cellulose fibers (both natural and artificial), glass and asbestos fibers, and fibrous sheet materials such as paper and fabric.

(4) *Laminated Plastics.*—This chapter summarizes information pertaining to composition, manufacture, utilization, and structural properties of laminated plastic materials.

(5) *Low-Pressure Molding.*—Pertinent information is given regarding the principal uses of this basic new process, the materials used, their preparation, tooling and equipment required, and the process of molding in the pressure range of 0–300 lbs. per sq.in.

(6) *Sandwich Constructions.*—This is the longest chapter in the book and offers considerable information on the following items: core, face, edgebanding and insert materials, and adhesives; flexural, column, and shear characteristics; miscellaneous design and service considerations; and applications of sandwich materials.

(7) *Structural Adhesives.*—A brief description is given of the various commercial adhesives now in use including the urea, melamine, phenol, and resorcinol formaldehydes; the polymerizing-thermosetting adhesives; and special adhesives for metals and glass. The structural bonding of metals (procedure and strength characteristics) is also covered.

(8) *Radomes and Microwave Windows.*—Various aspects of the radome design problem are briefly covered. The requirements of the antenna cover, its physical form, and the relationship between the electrical, structural, and production problems are discussed. The four basic radome solutions are listed, and a simplified design procedure is given.

Appendix I—Test Methods.—An outline is given of the purpose, apparatus, test specimens, procedure, data required, and results and calculations for the following tests: crushing, column compression, flexure, simple beam creep, and fatigue tests for sandwich materials; block shear tests of adhesives; single and double shear tests of metal to metal bonds tested in tension; and compression shear tests of honeycomb cores.

Appendix II—Derivation of Optimum Face-Thickness Ratio of Sandwich Panels.—Formulas are derived for the ratio of face thickness to total thickness of the panel, which will give a panel of minimum weight under column loading (see Chapter 6).

Appendix III—Partial List of Adhesive Trade Names and Suppliers—Numerous curves, figures, and tables are given throughout the volume to show pertinent data and characteristics of the materials discussed. Each chapter ends with an extensive list of references.

R. O. EnEarl
Research Engineer
Lockheed Aircraft Corporation

The Theory and Design of Gas Turbines and Jet Engines

By E. T. Vincent. New York, McGraw-Hill Book Company, Inc., 1950. 606 pp., figs. $7.50.

This book is almost entirely concerned with the thermodynamic and fluid-dynamic problems associated with gas turbines. Only a minor amount of information on mechanical design, combustion, materials, and regenerators is included. The book was written for the stated purpose of interpreting the gas-turbine technical literature that is available in language that would be familiar to the mechanical engineer. It is intended to be a textbook for senior students in the mechanical engineering course.

The first two chapters are devoted to a short review of the thermodynamic principles and gas-flow fundamentals that are used later. A chapter then follows which describes and defines the various propulsive efficiencies in connection with jet engines. The next three chapters examine briefly possible power-plant cycles, the cycle used by the turbojet engine, and the cycle used by the turbopropeller engine. These are followed by a short description of the overall performance characteristics of gas-turbine power plants. Typical gas-turbine power plants are then discussed. In addition to the usual aviation gas turbines, the Elliott and Allis-Chalmers stationary gas-turbine power plants are explained. The remainder of the book, with the exception of short chapters on combustion chambers, fuel systems, fuels, materials, and regenerators, is devoted to the development of the design theories of compressors and turbines. The centrifugal compressor, the axial-flow compressor, and the axial-flow turbine are each considered in two chapters. The first of these chapters deal with "theory," and the second with design of the component. A minor bit of mechanical design is included which is too abbreviated to be useful.

There is considerable duplication and overlapping of material presented in the various chapters of the book. This was intentional on the part of the author since presentation of the material in this manner "tends to impress it on the average student's mind better than a concentrated presentation at only one point."

Because of this duplication of material and the partial presentation of analyses at several different points, this book is not recommended as a reference work on gas-turbine design. The theoretical developments are overlapping, scattered, and choppy so that there are several possible locations to

refer to any given development. The design numbers, which have been derived from experimental testing, are likewise scattered throughout the book and are not necessarily close to the development of the theory with which they are to be used. In addition, there is a lack of consistency in the symbols and terms used in the different portions of the book which discourages easy reference.

It is this reviewer's opinion that repetition should be avoided in a textbook in order that material be presented as concisely and in as straightforward a fashion as possible. The repetition that is necessary for impressing it on the average student's mind can be made part of the classroom presentation. This book would, therefore, be most suitable for persons who were in the same position as the author stated his to be—"thrust into this new subject without notice and with little background other than that experience gained with superchargers, turbosuperchargers, and reciprocating internal-combustion engines." It would appear to be most suitable for engineers remote from the gas-turbine field, who wish to obtain, by their own efforts, the general understanding of the gas turbine.

O. E. RODGERS
Manager
Development & Research Engineering
Aviation Gas Turbine Division
Westinghouse Electric Corporation

Industrial Accident Prevention

By H. W. Heinrich. 3rd Ed. New York, McGraw-Hill Book Company, Inc., 1950. 470 pp., illus. $5.00.

Industrial Accident Prevention is a classic in its field. The author, H. W. Heinrich, Assistant Superintendent, Engineering and Inspection Division, The Travelers Insurance Company, has had more than 35 years' experience in industrial safety work. He is a recognized authority on safety and has often been a featured speaker on accident prevention.

Heinrich has combined, in nicely balanced proportions, the theoretical basic philosophy of accident prevention and practical "how-to-do-it" recipes. The book is highly readable and is an ideal choice for the executive or supervisor who wants to learn just how he can improve safety in operation.

Successful accident prevention work follows sound engineering principles: (1) Organize your plan of action, (2) find the facts, (3) analyze them, (4) select the remedy, and (5) apply the remedy.

One by one he takes the reader through each of these steps and shows just how to organize and follow through a successful safety program.

That the author's approach to accident prevention problems is intensely practical may be best illustrated by his example of the parent who observed his youngster holding a giant firecracker and a lighted punk. The child may

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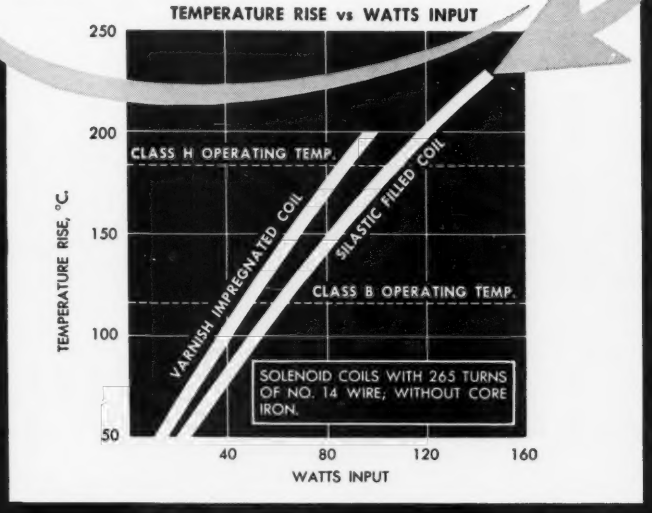

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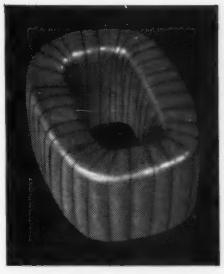

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have inherited reckless tendencies, the local laws controlling sale of fireworks may be ignored or nonexistent, but prompt parental action is the best immediate solution to the problem at hand.

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A new feature of the Third Edition is "Formula for Supervision," an analysis of the art of controlling the performance of persons.

Chapters on guarding, personal protective devices, illumination and vision, and occupational diseases provide a wealth of useful material that can be used directly or as a basis for solution of individual problems.

The author is a strong proponent of the theory that directed accident costs are on the average four times as great as direct compensated costs. Some of the items he cites as "hidden" charges do not agree with the thinking expressed in a recent study made by the National Safety Council, but difference of opinion makes horse racing. Even if the four-to-one ratio is liberally discounted, it still stacks the indirect cost of industrial accidents up to a sizable figure. The man who wants to cut these costs in his operation will find *Industrial Accident Prevention* a valuable guide.

JOHN A. O'DONNELL
Superintendent, Industrial Safety
American Airlines, Inc.

The Assisted Take-Off of Aircraft

By Rear Adm. Calvin M. Bolster. (James Jackson Cabot Fund Publication No. 9.) Northfield, Vt., Norwich University, 1950. 71 pp., illus., diagrs. $1.00.

Like its useful predecessors, this lecture brings together a considerable amount of information on a subject about which little information has been available. The choice of the lecturer was a particularly happy one, since assisted take-off has been a problem to naval aviation since the early days of flying and only a Navy man could do justice to certain aspects of its development. Admiral Bolster's direct association with catapult and jet-assisted take-off research and development fits him particularly for the job of telling about it, and his discussion, which is primarily from the engineer's point of view, makes this an especially useful contribution.

The earliest use of assisted take-off was made with rockets, but without benefit of stress analysts or aerodynamicists, and the record says that the Chinese inventor and his machine "disappeared in a blinding flash of fire and smoke." This was in the thirteenth century. In 1904 (not 1903) the Wright Brothers used a catapult, and the Navy used a compressed-air

catapult in 1912. Another form of assisted take-off is the high-speed aircraft carrier. Still another form, the "air carrier," was used by the British in the pick-a-back airplane in 1936, by the Navy in the fighter-carrying airships "Akron" and "Macon," and today in the take-off in the air of the supersonic Air Force X-1 from a B-29 bomber.

The need for extra thrust at take-off by rockets was foreseen by both the Air Force and the Navy before World War II, and work was in progress in 1941 on its development. The Navy was interested in its use on large flying boats in operations from rough seas or in unprotected waters—a problem solved by the solid-propellant rocket motor capable of 1,000 lbs. of thrust for 14 sec., which went into large-scale production during World War II. Jato (jet-assisted take-off) has proved itself far beyond flying boat applications, and Air Force experiments with landplanes and Navy experiments with carrier take-offs have shown many advantages of its use with both propeller- and jet-powered aircraft. Commercially, this application has been marked by the certification on October 15, 1947, of the Aerojet Model 14AS-1000 D-5 and the use of Jato in scheduled operations from La Paz, Bolivia, 13,398 ft. above sea level, beginning on June 1, 1949.

While Admiral Bolster discusses the entire field of assisted take-off, the catapult and Jato rightly claim most of his attention. The development of the catapult, largely a Navy enterprise, is related in detail, and the electric catapult of World War II emerges as an advance with implications for the future beyond its present use in the flight testing of jet aircraft at Patuxent River. For example, its application to jet air liners in the interest of safety and fuel economy is discussed.

A major part of the lecture is concerned with Jato. There are chapters on its development, its commercial application, and on estimating take-off characteristics with Jato. This last is a 21-page analysis presenting the results of various tests on flying boats and landplanes in nine graphs and 14 tables.

Admiral Bolster sees for the future a "diversified and useful employment of all forms of assisted-take-off," which will "contribute in an important way to the ever-expanding capabilities of military and commercial aircraft."

MAURICE H. SMITH
Librarian, I.A.S.

Airways Abroad; the Story of American World Air Routes

By Henry Ladd Smith. Madison, Wis., The University of Wisconsin Press, 1950. 355 pp. $4.00.

Airways Abroad, by Henry Ladd Smith, is a book on the history of foreign air mail written in a vein that makes it interesting as well as educational. It should be of particular value to the student and should provide as well a good historical background for the lawyer and executive.

It is highly recommended to the layman looking for inside information on the trials and tribulations of Pan American Airways in its fight for supremacy on the airways.

This book may not be as readable as Prof. Smith's history of our domestic air transportation in *Airways*, but *Airways Abroad* is also factual and reflects a considerable amount of research. The references throughout the book make it a valuable adjunct.

The analysis of the Chicago Conference and the notes on the Bermuda Agreement are especially well presented.

The student of air transportation will find it stimulating from beginning to end.

CHARLES FROESCH
Chief Engineer
Eastern Air Lines, Inc.

Book Notes

AERONAUTICS, GENERAL

Aviation from the Ground Up. John J. Floherty. Philadelphia, J. B. Lippincott Company, 1950. 157 pp., illus. $2.75.

As the author says, this is neither a textbook nor a treatise. It is an up-to-date story of what the author learned about aviation during several months of air travel and talk with engineers, pilots, mechanics, stewardesses, fixed-base operators, and passengers. A comparison with the author's *Aviation from Shop to Sky*, published in 1941, is an excellent way to compare the advances since that time in design, service, and in the use of the airplane. One useful feature is the firsthand information assembled here on such aspects of aviation as business flying, skywriting, crop spraying, or surveying. The author's impressions of air-line flying, jet-aircraft manufacture and testing, the G suit, or pressurized transports are fresh and entertaining.

AIRPORTS

Procedures for Testing Soils: Nomenclature and Definitions, Standard Methods, Suggested Methods. Philadelphia, American Society for Testing Materials, July, 1950. 418 pp., illus., diagrs. Cloth, $4.40; paper, $3.75.

This compilation of testing methods covers explorations and sampling, physical characteristics and identification, physical and structural properties, special and construction control tests, and bearing tests in place and dynamic properties. Subgrades, base courses, and surface courses for airports are included among the soils or aggregates tested.

ELECTRONICS

Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses. John F. Rider and Seymour D. Uslan. New York, John F. Rider Publisher, Inc., 1950. 982 pp., illus., diagrs. $9.00.

This comprehensive book, developed from the authors' *The Cathode-Ray Tube at Work* (1935), covers virtually all the field of activity where the cathode-ray oscilloscope is used and the underlying theory. The book consists of 22 chapters and three appendixes. The major emphasis is upon electronic applications, which occupy about one-third of the book. The reader is required to have a general knowledge of electricity and magnetism and of the rudiments of vacuum-tube theory and operation. There is a separate chapter showing about 1,600 complex wave forms and a chapter of more than 70 schematic diagrams of commercial oscilloscopes, with detailed descriptions and, in several cases, parts lists. A bibliography of about 200 references, arranged by chapters, is included. A table of characteristics of cathode-ray tubes, diagrams of standard cathode-ray basing, and a discussion of photographic applications are given in the appendixes.

Survey of Modern Electronics. Paul G. Andres. New York, John Wiley & Sons, Inc., 1950. 522 pp., illus., diagrs. $5.75.

This textbook is based on courses given by the author to mechanical, chemical, and industrial engineering students at the Illinois Institute of Technology. While a general knowledge of electrical engineering is required of the student, basic principles are reviewed usually before discussing the electronic devices and circuits upon which they are based. The emphasis is largely on a descriptive, rather than a mathematical, treatment, and specific applications are described for each type of tube. The final chapters deal with applications in instrumentation, communication, control, and heating. Bibliographies are included at the ends of chapters, and a general list of references is given in an appendix.

Radio Communication at Ultra High Frequency. John Thomson. London, Methuen & Company, Ltd., 1950. 203 pp., illus., diagrs. 21*s*.

The author's purpose is to present modern developments in radio communications using waves ranging from a few meters to a few millimeters. Circuits, tubes, power amplifiers, frequency multipliers, and oscillators for use at ultra-high frequency are discussed in the first three chapters, followed by a chapter on Receiver Input Circuits, by P. E. Trier. The final chapters cover modulation techniques, frequency control, and communication systems. The wartime and postwar developments of the Royal Naval Scientific Service furnish much of the material. The author is Professor of Physics and Electrical Engineering in the Royal Naval College at Greenwich.

Wave Guides. H. R. L. Lamont. 3rd Ed., Revised. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1950. 118 pp., diagrs. $1.25.

In this new edition of a book first published in 1942, newer developments are discussed in a separate new chapter, a number of new sections has been added, and the text modified to show modern trends. The bibliography has been increased from 65 to 122 references, including references on techniques and on loaded wave guides. The author is a Research Physicist with the Research Laboratories of The General Electric Company Ltd., at Wembley.

Principles and Applications of Waveguide Transmission. George C. Southworth. New York, D. Van Nostrand Company, Inc., 1950. 689 pp., illus., diagrs. $9.50.

In this textbook and working manual the conventional theories of electricity are presented in the first five chapters as they apply to networks, transmission lines, waves in free space, and wave guides. A considerable mathematical background is required of the reader. The discussion proceeds in the final seven chapters to a descriptive account of electrical transmission; waveguide transmission lines, elements, components, and radiators; electronic devices for wave-guide use; and modulation and demodulation by waveguide methods. About 175 references are included. Dr. Southworth is associated with the Bell Telephone Laboratories, Inc.

Electrical Communication. Arthur Lemuel Albert. 3rd Ed. New York, John Wiley & Sons, Inc., 1950. 593 pp., illus., diagrs. $6.50.

In this new edition of a textbook first published in 1934 and last revised in 1940, extensive revisions have been made, and new material has been added throughout. As the entire field of communications is covered, the extensive lists of references at the ends of chapters are keyed into the text to point out more detailed discussions of such topics as radio noise in aircraft, and a total of more than 600 references is included in the book. The author is Professor of Communication Engineering at Oregon State College.

The Metre-Kilogram-Second System of Electrical Units. R. K. Sas and F. B. Pidduck. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1947. 60 pp., diagrs. $1.25.

The unitary meter-kilogram-second (m.k.s.) system of electrical units was adopted by the International Electrotechnical Commission in 1938. The purpose of the authors of this book is to make accessible the scattered information on the system, largely in the form of working formulas, as an aid to the reader to obtain practices in the use of the new system. Data on the units of the system and a list of formulas are brought together in the final two articles.

Heaviside's Electric Circuit Theory. H. J. Josephs. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1950. 115 pp., diagrs. $1.25.

This book was first published in 1946. Although based on lectures given to electrical engineers, it develops one of Heaviside's later theorems with Carson's integral equation as a corollary and prepares the ground for the use of the operational calculus in fields other than electric circuits. The author is a Senior Physicist with the Post Office Engineering Department in England.

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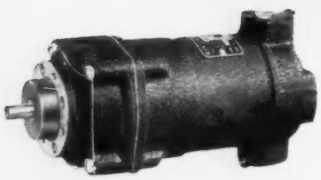

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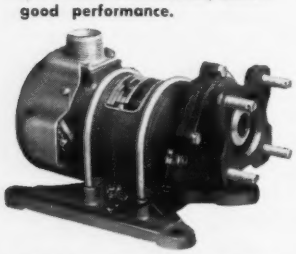

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SPECIAL APPLICATION
FRACTIONAL HORSEPOWER MOTORS

Static and Dynamic Electricity. William R. Smythe. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1950. 616 pp., diagrs. $8.50.

This new edition of a textbook for graduate students is larger by 56 pages than the edition of 1939 and has been extensively revised. The m.k.s. unit system is used, and the nomenclature was revised throughout. The treatment of electromagnetic waves has been expanded in two entirely new chapters, and the chapter on eddy currents has been rewritten. The 150 problems and the text contain methods and results not in the literature. The author is Professor of Physics at the California Institute of Technology.

Electrical Engineers' Handbook; Electric Communication and Electronics. Harold Pender and Knox McIlwain, Editors. 4th Ed. New York, John Wiley & Sons, Inc., 1950. Various paging, diagrs. $8.50.

This new edition of a standard handbook last revised in 1936 contains numerous revisions, and considerable material has been added on such topics as frequency modulation, pulse techniques, and aids to navigation. The total number of contributing specialists is 78, compared with 57 in the previous edition. Bibliographies are provided for each section.

ENGINEERING PRACTICES

Basic Engineering Drawing; A Text Integrating Engineering Drawing, Descriptive Geometry, Machine Drawing. William Wirt Turner, Carson P. Buck, and Hugh P. Ackert. New York, Ronald Press Company, 1950. 669 pp., illus., diagrs. $4.50.

In this integrated textbook, the introductory chapters cover drafting equipment, instruments, conventional lines, lettering, orthographic projection, and freehand sketching. Projection is discussed from the standpoint of descriptive geometry, and the student is led naturally into it as a continuation of orthographic projection, with emphasis on the auxiliary view or direct method of presentation. The final chapters on machine drawing apply the principles of the earlier parts of the book, with a comprehensive treatment of pictorial drawing. Abbreviations, definitions, American standards, and useful tables are included in appendixes. The authors are, respectively, Professor and Head of the Department of Engineering Drawing, Associate Professor, and Assistant Professor at the University of Notre Dame.

EQUIPMENT

ELECTRICAL

Design of Electrical Apparatus. John H. Kuhlmann. 3rd Ed. New York, John Wiley & Sons, Inc., 1950. 512 pp., illus., diagrs. $6.50.

This new edition follows the plan and purpose of the previous editions of 1930 and 1940, providing a textbook for engineering students using procedures and methods of the professional designer. The four sections cover direct-current machines, synchronous machines, induction motors, and transformers. Revisions and additions have been made in all sections, and the discussion of induction motors has been largely rewritten. The author is Professor of Electrical Design at the University of Minnesota.

The Commutator Motor. F. J. Teago. 2nd Ed., Revised. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1946. 80 pp., diagrs. $1.25.

This is the first revision of this book, which was originally published in 1930. The greatest change is in the chapter on the variable-speed motor (compensating commutator), where the discussion has been expanded to cover recent widespread commercial applications. The author concentrates upon the principle of energy transference to bring out the principles of the induction motor. A short bibliography refers the reader to detailed mathematical treatments.

Electric Fuses. H. W. Baxter. London, Edward Arnold & Company; New York, Longmans, Green & Company, 1950. 199 pp. illus. diagrs. $4.00.

This book summarizes work done by the British Electrical and Allied Industries Research Association on the design, performance, and application of fuses. The original reports have been supplemented by additional information for those more concerned with testing, application, and standardization. A bibliography of twelve papers referring to such applications as high-speed photography, pressure recording, and ballistic energy measurements is included.

MAINTENANCE

Aircraft Maintenance. Daniel J. Brimm and H. Edward Boggess. 2nd Ed. New York, Pitman Publishing Corporation, 1950. 475 pp., illus., diagrs. $5.00.

In this new edition of a standard work first published in 1940, additions have been made extensively in aircraft hydraulics and other developments, and some sections, such as woodworking, have been correspondingly reduced to their basic essentials. Metalwork, fabric work and finishing, rigging, handling and maintenance, and hydraulics are the principal topics discussed.

MANAGEMENT & FINANCE

Engineering Economy. H. G. Thuesen. New York, Prentice-Hall, Inc., 1950. 501 pp., diagrs. $6.65.

The author's purpose in this textbook is to aid the engineering student in the extension of quantitative thinking to the economic factors arising in most engineering situations, and to promote ability to make decisions where estimates and judgments are emphasized. Interest, depreciation, and cost calculations, evaluation of proposals, evaluation of public activities, and the comparison of alternatives are discussed in the greater part of the book. There are three chapters directly on the economy of operations, including capacity, loading, production and distribution costs, income, profits, and economic utilization of personnel. A bibliography of 40 books is included. The author is Head of the School of Industrial Engineering and Management at the Oklahoma Agricultural and Mechanical College.

The Foreman's Place in Management. T. G. Newton and Bleick Von Bleicken. New London, Conn., National Foremen's Institute, Inc., 1950. 150 pp., illus. $2.50.

In this discussion, written for foremen, the first section takes up professional foremanship and foreman-management problems, followed by basic and corrollary steps in the integration of foremen's functions with those of management. In the second part, the human relations aspects of a typical industry are reviewed from the actual practice of the Preston Manufacturing Company. Examples from industrial practice are given throughout. Mr. Newton is Director of Training of the Armstrong Cork Company and Mr. Von Bleicken is associated with the Labor Relations Institute in New York.

The Foreman's Manpower Job. John E. Gagnon and R. W. Verney. New London, Conn., National Foremen's Institute, 1950. 184 pp., illus. $2.50.

This is a thorough discussion of personnel management in industry written for foremen. The numerous examples used to illustrate both good and bad practices are effective. The authors are respectively, Manpower Manager, Bigelow-Sanford Carpet Company, and Personnel Manager, Maxwell House Division, General Foods Corporation.

MATERIALS

Metals at High Temperatures. Frances Hurd Clark. New York, Reinhold Publishing Corporation, 1950. 372 pp., illus., diagrs. $7.00.

The author's purpose is to compile the information recently made available on the properties of metals at elevated temperatures. The opening chapter takes up the theory of plasticity of metals with special reference to high-temperature effects and is followed by a chapter on test methods and equipment. The next five chapters deal with plain-carbon and low-alloy steels, chrome irons and moderately alloyed austenitic steels, highly alloyed austenitic steels, cobalt-base alloys, and nickel-base alloys. A separate chapter on noncommercial alloys summarizes Government sponsored research, with numerous tables of results. The final chapters deal with manufacturing processes, lower melting alloys, and scaling. A large amount of data is presented in tabular form on steels and on aluminum and magnesium alloys. Bibliographies are included at the ends of chapters, and there is an excellent detailed index. The author is associated with the U.S. Navy Material Catalog Office.

A Manual of Plastics and Resins in Encyclopedia Form. William Schack, Editor. Brooklyn, N.Y., Chemical Publishing Company, Inc., 1950. 547 pp., illus., diagrs. $10.

This encyclopedia contains about 1,500 subjects in alphabetical order, contributed by about 140 specialists, in addition to unsigned contributions for which credit is given in the introduction. Materials, products, processes, and equipment are covered. Articles on applications of plastics to aircraft, electrical appliances, refrigeration, and other fields give in tables the components for which plastics are used, the specific plastic used, and the properties making it suitable for that purpose. Bibliographies are often included—for example, in the article "Metals vs. Plastics." A list of trade names, including obsolete and foreign trade names, is given in an appendix, identifying each material by composition and manufacturer. This is an excellent reference book for the quick location of information on plastics.

A.S.T.M. Standards on Plastics; Specifications, Methods of Testing, Nomenclature, Definitions. 5th Ed. Philadelphia, American Society for Testing Materials, June, 1950. 610 pp., diagrs. $4.85.

This compilation was last revised in 1945. The present edition contains some 120 specifications and test methods for molding compounds, nonrigid plastics, phenolic laminated sheet and tubing, molded insulating materials, and electrical tests, covering strength, hardness, thermal, optical, and permanence tests. Eleven recommended practices and a list of definitions are included.

METEOROLOGY

The Climate Near the Ground. Rudolf Geiger. A Translation by Milroy N. Stewart and others. Cambridge, Harvard University Press, 1950. 482 pp., illus., diagrs. $5.00.

This translation of the second German edition of Professor Geiger's standard book includes additions by the author which make it virtually the equivalent of the third German edition, which was ready for publication in 1950. The translation was made possible by the loan, to the Blue Hill Observatory by the Air Force Weather Service, of the single copy of the second edition available. This is the standard work on microclimatology, concerned with the area not more than 2 meters from the earth's surface. Original sources are indicated in the bibliography of more than 800 references.

MILITARY AVIATION

Air Power: Key to Survival. Alexander P. de Seversky. New York, Simon and Schuster, 1950. 376 pp., illus. $3.50. Paper cover, $1.00.

Major de Seversky recommends that two-thirds of the national defense budget be devoted to the building of a long-range strategic atom-bombing air force and a supporting and defensive air force, to be under one Air Force commander. These forces should be supplemented by a strengthened Britain as our principal base across the Atlantic and by a rearmed industrial Western Europe. The mass land power of Russia with its mass tactical air support should not be rivaled but by-passed. Such actions as the Korean war should be avoided, since they will drain away resources better devoted to a strategic plan able to secure peace through its capacity to destroy industrial, supply, and administrative targets.

NAVIGATION

Flying the Omnirange. Charles A. Zweng. North Hollywood, Calif., Pan American Navigation Service; Annapolis, Md., Weems System of Navigation, 1950. 101 pp., illus. $4.00.

This book is designed as a pilot's guide to the very-high-frequency radio omnirange (VOR), distance-measuring equipment (DME), and the course-line computer. All available omnirange receiving equipment is described, and prices are given in detail. The background of the development of VOR is sketched, and a map of existing facilities and a glossary of omnirange terms are included. A typical example of omnirange navigation between San Francisco and Burbank is described from preflight stages to let-down and landing, and there are 77 study questions with answers.

ORDNANCE & ARMAMENT

Theory of the Interior Ballistics of Guns. J. Corner. New York, John Wiley & Sons, Inc., 1950. 443 pp., illus., diagrs. $8.00.

This is the first book on the theory of interior ballistics of guns to appear in English. The interior ballistics of rockets is not discussed. While advantage is taken of the classical theory, the approach is based upon recent results in which advanced physical research techniques have made better known the complex chemical and physical processes within a gun. Following a chapter defining the field, gun propellants and their thermochemistry are discussed, followed by two chapters on simple and more advanced ballistic methods. A short discussion of similarity relations and optimum problems is followed by extended chapters on the Interior Ballistics of Leaking Guns, and the Hydrodynamic Problems of Interior Ballistics. There is a separate chapter on some special types of gun, and the final chapter deals with Heat Transfer to Gun Barrels. Appendixes deal with the numerical solution of the equations of interior ballistics, some constants used in ballistics, and interpolation coefficients. Bibliographical footnotes are included throughout, and author and subject indexes are provided. Dr. Corner has been a Research Scientist with the British Ministry of Supply since 1939 and has been engaged in ballistics research through World War II and since.

POWER PLANTS

Internal Combustion Engines, Analysis and Practice. Edward F. Obert. 2nd Ed. Scranton, Pa., International Textbook Company, 1950. 596 pp., illus., diagrs. $7.25.

This new edition of a textbook originally published in 1944, by B. H. Jennings and E. F. Obert, is larger by 125 pages and has undergone extensive additions, revisions, and rearrangement. The basic purpose—to provide fundamental and factual knowledge of the broad field of internal-combustion engines and their components for engineering students—has been retained. Topics discussed in new separate chapters in the present edition are theories of combustion and detonation, pressure and pressure measurement, knock and the engine variables, engine characteristics and valve timing, and lubrication. There are separate chapters in this edition also on spark-ignition and compression-ignition engines and on compressors gas turbines, and jet propulsion. Chapters on such topics as testing, thermodynamics, cycle analysis, combustion charts, fuels, carburetion, injection, and exhaust gas and the air-fuel ratio have been revised and their bibliographies brought up to date. The author is Professor of Mechanical Engineering at Northwestern University.

PRODUCTION

Machining—Theory and Practice. A Series of Thirteen Educational Lectures, Presented to Members of the A.S.M. During the Thirty-First National Metal Congress and Exposition. Cleveland, American Society for Metals, 1950. 504 pp., illus., diagrs. $6.50.

Contents: Metal Cutting: Art to Science, Hans Ernst. Metal Cutting Research—Theory and Application, M. E. Merchant. Cutting Fluid Theory, M. C. Shaw. Materials and Machinability, F. W. Boulger. Development of the Macrostructure of Metals by Machining, L. M. Clarebrough and G. J. Ogilvie. Metallurgy and Machinability of Steels, J. D. Armour. Tool Steels, G. A. Roberts. Cemented Carbide Tool Materials, J. C. Redmond. Heat in Metal Cutting, A. O. Schmidt. Evaluation of Machinability of Rolled Steels, Forgings, and Cast Irons, Michael Field and N. Zlatin. Tool Life Testing, O. W. Boston. Some Metallurgical Aspects of Grinding, L. P. Tarasov. Economics of Machining, W. W. Gilbert.

Recommended Practices for Resistance Welding (Cl.1–50). New York, American Welding Society, 1950. 58 pp., diagrs. $1.00.

This revised and enlarged standard was originally issued in tentative form in 1946. Welding schedules are included for spot and seam welding mild and medium carbon, low-alloy, and stainless steels, and nickel, Monel, Inconel, and magnesium alloys, and recommended practices are given for projection welding of low-carbon and stainless steels and for flash welding of low- and medium-forging strength steels. The section on testing includes the new peel test and additional data on statistical quality control.

Symposium on Usefulness and Limitations of Samples. (Reprinted from American Society for Testing Materials, Proceedings, Vol. 48, 1948.) Philadelphia, American Society for Testing Materials, 1948. 39 pp., diagrs. $1.00.

Contents: Introduction, H. F. Dodge. Sampling and Its Uncertainties, S. S. Wilks. On Variation in Materials, Testing, Sample Sizes, Leslie E. Simon. The Amount of Inspection As a Function of Control of Quality, G. R. Gause.

Centrifugal Casting by the Cire Perdue Process. C. Rosen. Bruce Grove, Watford, Harts., The Bruce Publishing Company, 1950. 204 pp., illus., diagrs. £2 12*s*. 6*d*.

The author's aim is to collate the available information on the lost-wax process of casting. The preliminaries of pattern and mold making are covered in introductory chapters, and the entire process is discussed in seven succeeding chapters, ending with cleaning and finishing. There is a final summary chapter and a review of patents. Though written primarily for the manufacturing jeweler, the volume may be used by the dental and industrial caster.

PUBLIC SPEAKING

Speaking Can Be Easy . . . for Engineers, Too. New York, Engineers' Council for Professional Development, 1950. 24 pp., illus. $0.50.

This concise manual is the result of three years of work by a special committee and is designed to help engineers become better speakers and hold better meetings. Humorous illustrations are used, and the presentation is arranged for quick reading. There are two parts, dealing with The Speaker and with Meetings. The part on the speaker covers such points as planning and preparation, attention patterns, and platform and microphone manners. Pointers for the chairman are covered in the section on meetings, including introduction of the speaker, question handling and panel discussions, audiences and attendance, and publicity. Check lists are provided for both speaker and chairman.

REFERENCE LITERATURE

BIBLIOGRAPHIES

Author Index to Reports and Memoranda of the Aeronautical Research Council, 1909–1949. (Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2570.) London, H.M. Stationery Office, 1950. 142 pp. 15*s*. British Information Services, New York. $3.50.

This index by authors of *R. & M.'s* published from 1909 through 1949 covers the series approximately through No. 2298. Some recent numbers that were unpublished at the time of compilation are omitted, as are *R. & M.'s* that were not published in the bound volumes. *R. & M.'s* compiled by the staffs of such agencies as the Royal Aircraft Establishment and the National Physical Laboratory are indexed under the name of the compiling agency.

List of Reports Published by the Nationaal Luchtvaartlaboratorium. Supplement, 1949. Amsterdam, 1950. 10 pp.

This second supplement to the list of reports dated October, 1947, covers over 50 reports issued between December, 1948 and January, 1950, including some miscellaneous reports and papers bearing no numbers which were published in technical journals during that period.

DICTIONARIES

Condensed Chemical Dictionary. Francis M. Turner, Editorial Director. 4th Ed., Completely Revised and Enlarged by Arthur and Elizabeth Rose. New York, Reinhold Publishing Corporation, 1950. 726 pp. $10.

This excellent dictionary was last revised in 1942. The present edition contains 5,000 more materials and processes than the last, or about 23,000 altogether. The properties, chief known constituents, constants, derivation, grades, uses, type of shipping container, and shipping regulations for each item are given. Materials sold under trade or brand names are liberally included, with reference to 400 manufacturers who supplied information. The cross indexing is thorough.

DIRECTORIES

Sell's National Directory and British Exporters' Register. British Aviation Supplement. London, E.C. 4, Business Directories, Ltd., 1950. 96 pp.

This excellent directory contains an alphabetical list of over 1,700 British firms, with postal and cable addresses, and a classified trade section listing companies and postal addresses under some 500 headings. The coverage of manufacturing and commercial aviation firms includes aircraft and engine manufacturers, parts, accessories, and materials manufacturers and suppliers, and air lines, charter operators, and other aviation services. Separate lists of classified trades headings are furnished in English, French, and Spanish, and there is a separate section giving details of civil aircraft for export.

HANDBOOKS

Physical Constants, Selected for Students. W. H. J. Childs. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1949. 77 pp., diagrs. $1.25.

The compiler's purpose is to present tables of the constants, in pocketbook form, giving the most recent determinations as exactly as needed for everyday use. The compilation was first published in 1934 and was revised in 1939, 1943, and 1946. Useful mathematical tables are included.

HISTORY

Sea Warfare, 1939–1945; A Short History. John Creswell. London and New York, Longmans, Green and Company, 1950. 344 pp., maps. $6.00.

In this history of the naval operations of World War II, Captain Creswell combines analysis with the factual relation of events with a most satisfactory result. His conclusions are that aircraft and their missiles (torpedoes, bombs, and rockets) replaced large naval guns during the war, and that carrier-based, rather than shore-based, aircraft proved to be of first importance in battles involving naval power. The use of radar in aircraft operations, for antiaircraft artillery, and in antisubmarine action demonstrated that this was perhaps the most important single technical device developed for sea warfare, but the torpedo is given a high place as a weapon against ships. Operations at long distances from bases and the

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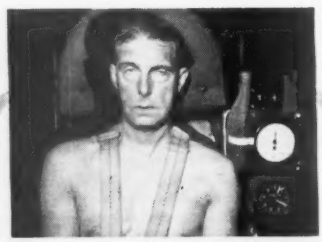

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SCIENCES GENERAL

PHYSICS

Relativity Physics. W. H. McCrea. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1950. 87 pp., diagrs. $1.25.

This book was originally published in 1935 and revised in 1947. The author's purpose is to furnish accessible deductions of those results of relativity theory which find most frequent applications in physics, without recourse to tensor calculus. Following a separate chapter on special relativity and the Lorenz transformation, the discussion takes up relativity kinematics, mechanics, optics, electromagnetic theory, atomic physics, thermodynamics, statistical mechanics, and hydromechanics. The author is a Professor of Mathematics at the University of London.

The General Principles of Quantum Theory. G. Temple. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1948. 120 pp. $1.25.

This book was originally published in 1934 and revised in 1942 and 1946. It is designed to be an introductory account of general principles forming the physical basis of the quantum theory. Mathematical techniques are considered only as appropriate expressions of physical concepts, though the fundamental methods covering the theory of linear operators and of matrices are developed in the first chapter. Professor Temple teaches mathematics at King's College in the University of London.

Wave Mechanics. H. T. Flint. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1950. 131 pp., diagrs. $1.25.

This book was originally published in 1929 and revised in 1931. The theory of wave mechanics is discussed as developed by de Broglie and Schrödinger, based on conceptions of continuity, and the quantum mechanics is largely omitted except in the final chapter on the first-order equations of the quantum theory and in the bibliography.

Cosmological Theory. G. C. McVittie. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1949. 103 pp. $1.25.

In this edition of a book first published in 1937, minor errors have been corrected, but a major revision has not been attempted. The emphasis is upon developments most easily comparable with observation, but there is a separate chapter on the tensor calculus. In the final chapter the Milne kinematical theory of the universe is generalized to any Riemannian space. The author is Professor of Mathematics at Queen Mary College in the University of London.

X-Rays. B. L. Worsnop and F. C. Chalkin. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1950. 126 pp., diagrs. $1.25.

This book was first published in 1930 and revised in 1946 to include new advances. The discussion includes determination of wave-length and X-ray spectroscopy, X-ray spectra, scattering of X-rays, optical phenomena, and photoelectrons and ionization. A bibliography of about 28 books and articles is included.

Ionization Chambers and Counters. D. H. Wilkinson. London and New York, Cambridge University Press, 1950. 266 pp., diagrs. $4.50.

The author's purpose is to present the principles of operation of the ionization chamber, the proportional counter, and the Geiger counter as an aid in the design of new chambers and counters. The first part of the book deals with phenomena of ionization, phenomena governing the behavior of counters, and the electrostatics of pulse formation. Each of the classical types of counter is taken up in a separate chapter in the last half, with a final chapter on the statistical aspects of electric counting. There is a bibliography of about 240 items. The author is University Demonstrator in Physics at Jesus College, Cambridge.

STRUCTURES

Strength of Stainless Steel Structural Members As Function of Design. Michael Watter and Rush A. Lincoln. Pittsburgh, Allegheny Ludlum Steel Corporation, 1950. 153 pp., illus., diagrs. $5.00.

The basic properties are described of light-gage stainless strip of various tempers at room temperature, and a design procedure for calculating the allowable loads of structures made from it is given. The first 84 pages and 61 figures are devoted to basic tension and compression data, combined moduli data for use in compression and their application to the compression of columns, and column behavior of an entire section. Following three examples of the calculation of the load that a column is able to carry, a simplified procedure is presented for calculating column failure that occurs through buckling in compression without twisting. Behavior in bending and shear is then discussed, and the book concludes with application of the data to the analysis of open-section columns in compression which fail by twisting. The reduced modulus described by Timoshenko in his *Theory of Elastic Stability* is used in the design procedure on the basis of tests showing its applicability to stainless steel. A bibliography of 18 items is included. Doctor Watter is Director of Research of The Budd Company, and Dr. Lincoln is associated with the Allegheny Ludlum Steel Corporation.

THERMODYNAMICS

Thermodynamics; An Advanced Treatment for Chemists and Physicists. E. A. Guggenheim. Amsterdam, North-Holland Publishing Company; New York, Interscience Publishers, Inc., 1949. 394 pp., diagrs. $6.50.

This book is addressed equally to physicists and chemists, but not to engineers. It is written for the graduate but is useful to undergraduates intending to specialize in physical chemistry or chemical physics. The third law is introduced early and is used throughout the book, and there is an early chapter on statistical mechanics. Applications to solutions, interfaces, electrochemistry, dielectrics, and paramagnetics are included. The author is Professor of Chemistry at Reading University.

Special I.A.S. Publications

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101	Introduction to Shock Wave Theory—J. G. Coffin.	$2.65	$3.50
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I.A.S. News

(*Continued from page 15*)

• **Radioplane Company . . .** The OQ-19 target plane has been remote-control-tested by a ground pilot twisting dials on a tiny box 10 miles away. The key to this new and effective combination of radio control and radar tracking is a new automatic pilot, a device that holds the target plane on any course desired by the operator. A 38-in. diameter cargo-type parachute, released by the control operator or by any interruption of the radio carrier wave, lands the aircraft. Another automatic device frees the chute the instant the target plane touches the ground.

• **A. V. Roe Canada Limited . . .** The Orenda turbojet has been flown for the first time in a North American F-86 Sabre.

• **Ryan Aeronautical Company . . .** The Navion personal-business plane production will be suspended in 1951 so that the company's entire facilities and personnel can be devoted to military needs, according to an announcement by T. Claude Ryan (M.I.A.S.), President. Officials state that production of Navions for commercial sale will be reinstated at the earliest feasible date and consistent with the country's military aeronautical requirements. . . Beginning November 1, awards are to be given to business or professional men who fly their own Navions the highest total hours during monthly, quarterly, and annual periods.

• **Tinnerman Products, Inc. . . .** A new research laboratory is to be constructed adjacent to the office section of the new factory that was formally opened last September. The research laboratory will cost approximately $200,000.

• **Trans World Airlines, Inc. . . .** The 20th anniversary of the first all-air transcontinental passenger service was observed on October 25. Two Ford trimotors, "Tin Geese," bearing T.W.A. markings, took off from Newark Airport shortly after 8:00 a.m. on October 25, 1930, for Los Angeles and arrived there about 36 hours later. The elapsed time included 26 hours of flying time and an overnight stop in Kansas City. . . Scheduled transcontinental all-cargo flights using DC-4 equipment were inaugurated on November 1. The DC-4 flights operate between Los Angeles, Phoenix, Albuquerque, Kansas City, Chicago, Philadelphia, and New York. . . A new sales area, known as the Pacific-Orient Region, has been created. Headquarters will be in Los Angeles, and the territory will extend as far as Burma.

• **Solar Aircraft Company . . .** The engineering organization has been split into two divisions because of increasing pressure of development work. William C. Heath (M.), Solar's Chief Engineer, heads the Aircraft Products Division, and Paul A. Pitt was named Chief Engineer of the Development Section.

• **Stratos Division, Fairchild Engine and Airplane Corporation . . .** A quick, reliable method of disconnecting generators and alternators from their engine drive in the event of an in-flight failure has been developed. The emergency disconnect equipment makes it possible for pilots of multi-engined aircraft to keep an engine running even though a failure has occurred in an alternator or generator and, by stopping rotation of the defective accessory, eliminates the hazard of a fire and prevents destruction of the faulty unit. The first of the new disconnect mechanisms was designed for use on the Pratt & Whitney R4360 engine.

• **Westinghouse Electric Corporation . . .** Dr. Howard M. Elsey, Consulting Chemist, has found a way for carbon brushes to create their own lubrication by treating these brushes with a special chemical compound belonging to the same family as table salt. This new ingredient promotes the formation of a lubricating film that prevents harmful friction at the highest altitude attainable. It is claimed that this new chemical treatment can stand up under both the high heat of jet-engine starting and the thin dry sub-zero air of stratosphere flying.

I.A.S. Sections

Baltimore Section

H. E. Nietsch, *Secretary*

The Baltimore Section was treated to a bombardment of atomic radiation during the initial fall meeting held at the Engineer's Club, October 10. In lieu of the three distinct effects attending an atomic explosion—viz., concussion, flash burn, and the penetrating irradiation—the members were exposed to a presentation of that timely topic by two experts.

Ralph C. Sturm, Physicist, Department of Radiology, The Johns Hopkins University, introduced the subject with a review of atomic particles and their relationship. On this foundation, the lecturer expanded to the application of principles toward the production and uses of atomic radiation. The talk was concluded with a brief discussion of the related field of X-ray and other radiation measurement.

The background of Mr. Sturm's talk had been obtained through his present activity in the development of instruments for the measurement of radiation. He spent several years during World War II at the Mayo Clinic on the development of electronic instruments for human centrifuge experiments.

The effects of both controlled and uncontrolled radiation on the human body formed the subject of David M. Gould, M.D., Associate Professor of Radiology, The Johns Hopkins Hospital. The utility of controlled radium therapy was strikingly illustrated by a group of color slides of "before and after" pathological growth conditions.

Dr. Gould then presented an analysis of the physical conditions attending an atomic explosion, including current medical thinking on organized relief for the victims. Within a 1-mile radius of "bomb zero"—the ground location directly under the explosion—practically all human life is obliterated. The shock wave attains a pressure of hundreds of atmospheres sufficient to "blow down" concrete buildings. The high-intensity infrared radiation completely sears human skin. It travels in straight lines only, however, and can be considerably blocked by white cloth. The most insidious effect comes from the high-energy gamma rays that can penetrate deeply into concrete or lead. The consequent ionization occurring within human flesh forms a most serious challenge to treatment among survivors.

Dr. Gould concluded a most stimulating lecture with slides relating to the extent of human devastation at varying distances from "bomb zero." At 3 miles, survivors have an excellent chance of complete and rapid recovery.

The meeting was ended by a color film showing the mechanism by which chain reaction leads to the explosion, plus scenes of the vicinity damaged in consequence.

Chicago Section

Alfred F. Stott, *Secretary*

On October 5 the Chicago Section held its first meeting of the 1950–1951 season at Globe Corporation's Aircraft Division in Joliet, Ill., with Globe being host at a fine dinner and tour of their engineering and shop facilities. One hundred and twenty-five members and guests attended the gathering. The girls in the office prepared and served the dinner, and the tour was conducted by engineering personnel. A feature of the tour consisted of viewing the starting and operation of a pulse-jet engine.

(*Continued on page 86*)

Meet Your Section Chairmen

Douglas A. King

Hampton Roads Section

Douglas Andrew King is an Aeronautical Research Scientist and Project Engineer in Tank No. 2, N.A.C.A., Langley Air Force Base, Va. With N.A.C.A. since 1942, he has also been in Tank No. 1 and the Hydrodynamics Analysis Section of the Hydrodynamics Division. His job at present is to conduct investigations dealing with various phases of the hydrodynamic performance of water-based aircraft, such as take-off and landing stability, resistance, spray, etc. His interest lies primarily in hydrofoils and their applications, although there are times when he has "been interested in not falling into the tank."

Mr. King finds it hard to determine just when and for what reason he first considered aeronautics as a career. As a matter of fact, it would appear to be a composite choice. Perhaps the Sea would have been a more obvious choice, for Douglas King is the son of a Navy man and the grandson of an old windjammer sailor. He listened avidly to his seafaring grandfather as he told of his experiences, but by the time Mr. King was born in Norfolk, Va., on March 23, 1921, the days of the sailing ships were well over. Transportation, which forms the basic pattern in the life of any Navy family, was another possible career that appealed to him. However, there was Engineering in which he was also interested. He found his solution by combining all of the three possible careers in the selection of aeronautics, or as he tells it: "With the passing of the sailing vessel, the airplane came to me to be the most finely balanced and wonderful engineering product; combine aeronautics with the sea and you get water-based aircraft."

His father's profession necessitated Mr. King's attending various institutions of secondary education. These included grammar school in Cork, Ireland, and high schools in Portsmouth, N.H.; Old Orchard, Me.; Vallejo, Calif.; and San Diego. College, however, was a different story. He stayed at Rensselaer Polytechnic Institute during his 4 years of undergraduate work and was graduated from there in 1942 with a Bachelor of Aeronautical Engineering degree.

Mr. King and his wife, the former Daisy Mae Hadlock, are parents of $4\frac{1}{2}$-year-old Steven and $3\frac{1}{2}$-year-old Linda. Both Mr. and Mrs. King are "addicted" to science fiction and attend the local gathering of the other science-fiction fans. Both are interested in the Hampton Little Theatre. Mr. King tells us: "Although I have appeared briefly in a couple of productions, my preference is for backstage work . . . . Recently, I have specialized in lighting and have lit such of our productions as Anderson's *Joan of Lorraine* and Wilder's *Our Town*." He is also Treasurer and a Director of the Engineer's Club of the Virginia Peninsula.

Mr. King has written sundry reports on his speciality. Some of his papers still remain covered by security classifications. However, among those that have been made public are: "Tank Tests of a Model of the PBY-type Outboard Float with Hydrofoils" (December, 1943); "Effect on Low-Speed Spray Characteristics of Various Modifications to a Powered Model of the Boeing XPBB-1 Flying Boat" (coauthored with Newton A. Mas, June, 1945); and "General Tank Tests of a $\frac{1}{10}$-Size Model of the Hull of the Boeing XPBB-1 Flying Boat" (coauthored with Mary B. Hill, July, 1946).

Douglas C. Heimburger

Wichita Section

The son of a medical missionary and his wife, Douglas C. Heimburger was born 30 years ago in Weisein, China. He had completed his grade school education in China before his family returned to the United States to reside permanently. Mr. Heimburger attended high schools in St. Louis and in Springfield, Mo. He received his Bachelor of Science degree in Physics from Drury College and his Master's degree in Aeronautical Engineering from Purdue University.

Mr. Heimburger started flying in 1939 in Springfield in the Civilian Pilot's Training Program. He then became an Instructor in the C.P.T.P. and was later commissioned in the U.S. Army as a civilian pilot. He was both Flight Instructor and Ground School Instructor at Randolph Field, Tex., from 1942 to 1945. In the Central Pilot Instructors' Course at Randolph, he helped set up a course for pilots called "Analysis of Maneuvers." He was a Test Pilot at Wright-Patterson Air Force Base, Dayton, Ohio, in 1945, and "flew almost everything the Air Force had." At Purdue, he taught a flight-test course to senior engineering students and instructed flying at the School of Aeronautics.

Douglas Heimburger first came to Boeing Airplane Company, with which he is now associated, in 1948 as a Test Pilot for the YL-15 Scout liaison plane. He took the plane to Fort Bragg, N.C., where he demonstrated it before the ground forces. After the huge six-jet, swept-wing B-47 bomber was developed at the company's Seattle plant, he went there to participate in experimental flights. He returned to Wichita when two experimental models of the 60-ton bomber were brought there at the time its production was initiated at Boeing—Wichita. Officially, his position is XB-47 Project Pilot.

Mr. and Mrs. Heimburger are the parents of Cynthia, aged 4, and Bruce, aged 1.

Correction

Henry Kerr
Detroit Section

J. Parker Van Zandt
Washington Section

The photos on the left were inadvertently switched in the write-ups of Section Chairmen on page 84 of the December *Review*. We offer our sincere apologies to both members.—*Ed.*

BETTMANN ARCHIVE

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(*Continued from page 84*)

Following the dinner and tour, a business meeting was called to order by Chairman K. L. Burroughs at 8:20 p.m. All Officers, Advisory Board, and Committee Members were introduced. The Historian's book was shown and put on exhibition. The newly acquired "Register of Members and Guests" was described and circulated for signatures. A rousing vote of thanks was extended to the Globe Corporation and their personnel for making the enjoyable evening possible. Robert H. Wendt, Vice-President of Aircraft Division, Globe, and I.A.S. Program Chairman, responded and welcomed all on behalf of Russell Gage, Vice-President and General Manager. The program for the coming year was discussed. Mr. Gage introduced Charles Bonnette, of the Engineering Department, who was in charge of the evening's activities. C. Lusty, Chief Engineer, was introduced and showed various models of Globe Target Airplanes, describing each. He then commented on movies showing the testing and flying of their various target airplanes. Refreshments were served, and the meeting closed at 10:30 p.m.

▸ The November 3 meeting of the Chicago Section was held in the facilities of the Western Society of Engineers. Approximately 35 members and guests gathered in the lounge for a social period followed by a dinner in the main dining room.

At 8:15 p.m., Section Chairman K. L. Burroughs called the meeting to order in the auditorium. Approximately 50 members and guests were present. The Chairman briefly mentioned the joint meeting to be held on December 5 with the Chicago Section of the S.A.E. Plans for the winter and spring meetings were announced. Mr. Burroughs then introduced Boone T. Guyton, Chief Test Pilot, Chance Vought Aircraft Division, United Aircraft Corporation, as guest speaker.

Mr. Guyton spoke about the engineering and development problems encountered with the Chance Vought F7U1, the Cutlass. He discussed briefly the thought behind a tailless airplane, the two-position landing gear, leading-edge slats, irreversible boost controls, and cabin pressurization, as well as problems encountered in using dive brakes and special control devices. He mentioned many interesting situations relative to the test-flying of new military designs. A colored movie showing the Cutlass in flight was shown. A lengthy and interesting question-and-answer session followed the talk. The meeting adjourned at 10:15 p.m.

Dayton Section

Major W. A. Barden, *Secretary*

Dr. Andrew Fejer, Chairman, Department of Aeronautical Engineering, University of Toledo, Ohio, addressed some 50 members and guests of the Dayton Section at the Biltmore Hotel on October 24.

In speaking on the subject "Aerodynamics of Propulsion Systems," Dr. Fejer reviewed the airflow requirements of reciprocating engines compared with those of jet engines. Since ratio of air handled by a jet engine to that handled by a reciprocating engine is on the order of 12 to 1, it is readily seen that "aerodynamics of propulsion systems" is a subject of major importance. The preliminary remarks were devoted to a statement of the fundamental factors affecting the choice of location of the various components of propulsion systems to attain the most favorable aerodynamic conditions.

Dr. Fejer next discussed the aerodynamic relationships affecting induction-system airflow for jet engines with and without using ram air for both subsonic and supersonic velocities. This was followed by a discussion of the effects of nozzle contour on exit pressure of the exhaust stream and, consequently, on the effective thrust developed.

Basic concepts of the diffusors, guide vanes, and the like were discussed, as well as the dimensional limitations imposed on those items as a result of structural requirements. In concluding, Dr. Fejer stated that we cannot separate internal from external phenomena because of the contradictory results that would be obtained.

Hagerstown Section

L. T. Waterman, *Secretary*

The meeting on July 11 was held at Moose Hall and was called to order by Chairman Dan W. Weller.

The minutes of the last meeting were read. Mr. Maloney recommended that the meetings be discontinued for the summer. The suggestion was made that the next meeting be a picnic followed by the annual dinner meeting. It was decided to have the dinner meeting for members and guests in September.

The Chairman was instructed to appoint a nominating committee to prepare a slate of candidates for officers for the coming year. The election of officers is to be held prior to the dinner meeting, at which time the new officers will be installed.

H. C. Billings introduced the speaker, R. W. Kellhofer, Customer Relations Director, Fairchild Aircraft Division. Mr. Kellhofer gave a talk on the present state of the aircraft cargo-carrier industry and the requirements of the Air Force. He made specific statements as to the responsibility of the manufacturer in providing modern designs to implement the defensive and offensive potentials of our country.

▶ The Hagerstown Section held its annual dinner meeting at Fountainhead Country Club, October 17, with 77 members and guests present.

The Chairman, Dan W. Weller, introduced the newly elected officers: Chairman, Robert Gilson; Vice-Chairman, William Maloney; Secretary and Treasurer, James Gibson; Advisory Council, A. J. Thieblot, R. W. Lessard, P. E. Novgard, and D. Weller; and Representative to Area Nominating Committee, Bert Lindner.

The financial report for the fiscal year ending September 30, 1950, was read by Mr. Waterman, Secretary-Treasurer.

Armand J. Thieblot, Chief Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation, talked on future activities of the Section. He proposed that a contest be initiated and a prize of $100 be awarded to the member submitting the best paper for presentation at the I.A.S. Annual Meeting. Papers would be submitted to a panel of judges for review before being sent to the national organization. Mr. Thieblot suggested that Ben Howard, General Manager, be contacted to obtain approval for the donation of the prize by the Fairchild Aircraft Division.

The address of the evening was given by Lt. Col. Howard E. Kreidler, Deputy Assistant Director, Operations, Military Air Transport Service. He spoke on "The Air Lift to Japan and the Support of the Korean Operations."

Hampton Roads Section

George White, *Secretary*

Organization of the Hampton Roads Section of the I.A.S. has been recently completed by members residing in the Hampton-Newport News-Norfolk area of Virginia. The movement to form a local section in this region was initiated last spring by a Steering Committee, consisting of Douglas A. King as Chairman, and William M. Bland, Robert W. Miller, and George White as Committee Members.

A preliminary meeting of the I.A.S. members was held in June, and at that time it was decided to delay formation of an active Section until fall in view of the many vacations and other summer activities that would detract from meeting attendance.

Therefore, the first regular meeting was held on September 29, at which time the Section heard an interesting and informative talk on "Army Light Aviation." The speaker of the evening was Major John Oswalt, Air Division, Research and Development Section, Headquarters, Army Field Forces.

Major Oswalt discussed the desirable and undesirable features of the aircraft operated by the Army at the present time, pointing out the great need for shorter landings, quicker take-offs, and reduced maintenance cost. Extreme simplicity of aircraft and power plant were emphasized as being of prime importance in obtaining maximum serviceability at advanced stations in the field.

A series of slides was presented to illustrate the various types of aircraft used by the Army Field Forces, and a motion picture depicted light airplanes functioning as members of Army units for reconnaissance, target spotting, messenger service, and emergency wire-laying.

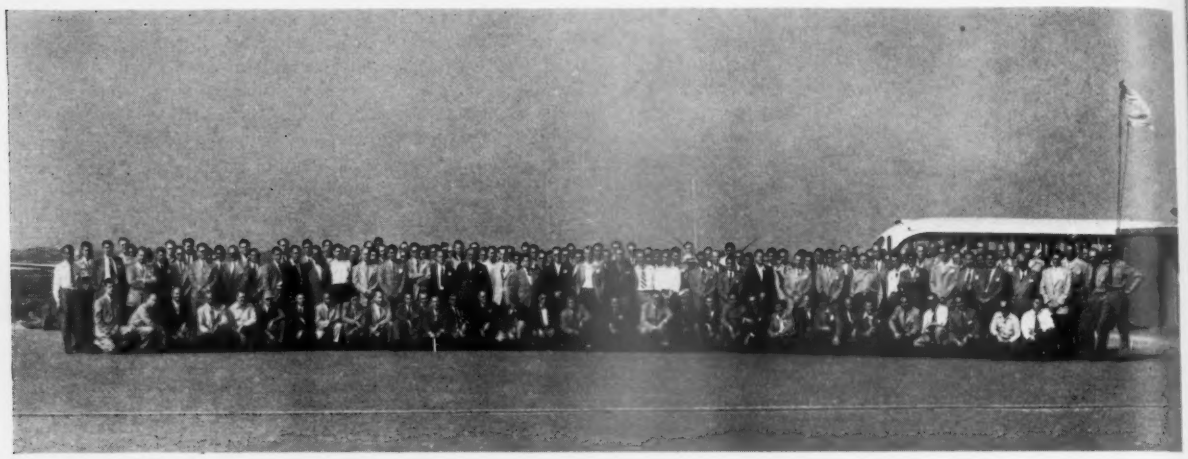
At the conclusion of the talk, a short business meeting was held, at which the officers were elected for the coming year. The following men, all members of the staff of N.A.C.A.'s Langley Aeronautical Laboratory, were selected to fill the respective offices: Chairman, Douglas A. King; Vice-Chairman, Charles Merlet; Secretary, George White; and Treasurer, William Solomon.

Following adjournment of the business meeting, an informal session was held with Major Oswalt, who answered numerous questions and engaged in an off-the-cuff discussion of today's light planes.

Los Angeles Section

H. A. Storms, *Secretary*

On September 14, approximately 150 members of the Los Angeles Section had the pleasure of visiting the Navy's Air Missile Test Center at Pt. Mugu, Calif. Five large busses were chartered for the trip and departure was taken at approximately 8:00 a.m. Upon arrival, the guests were welcomed aboard by the acting Commanding Officer. In turn, several other base officers and Civil Service Navy representatives gave the group an insight as to the organization and multiple operations of this large and important test center. Following the indoctrination period, "All Hands"



FIELD TRIP

Members and guests of the Los Angeles Section are shown during an I.A.S. inspection tour on September 16 of the U.S. Naval Air Missile Test Center, Point Mugu, Calif. Approximately 160 members participated.

were organized into smaller groups and the actual inspection of specific installations and projects began.

Elaborate mock-up installations and actual full-scale models were on display for inspection at the various projects. Short, interesting lectures were presented at each project, followed by highly profitable question-and-answer periods.

Among the highlights of the afternoon were demonstration flights of a Navy pulse-jet and propeller-driven target drones. The small craft were expertly flown from the catapulted take-off to final descent by parachute. Following movies of missile tests shown in the auditorium, the visiting party departed for Los Angeles.

Naval officers and men, together with several representatives of contractors, gave freely of their "off-hour" time to provide the I.A.S. members with a most enjoyable and profitable field trip.

▶ An outstanding specialists' meeting was held on the evening of October 5 when a lecture was presented to approximately 70 people by W. E. Fellers, Assistant Chief Aerodynamicist, North American Aviation, Inc. Mr. Fellers' topic was the "Development of a High-Load Capacity, 6-Component Internal Balance." The design and construction of the balance was accomplished by North American Aviation personnel for use in high Mach Number wind-tunnel tests of a sting-mounted model, wherein an internal six-component balance of small volume was required to handle high loads (up to 1,000 lbs.) with a high degree of accuracy. Further design requirements were satisfied to provide a balance with an exterior that was a concentric annular ring having no proturberances beyond the case as to permit location in the duct of the model. In addition, provisions were made to allow for ten to 20 pressure leads and electrical leads through the balance system. The balance is a flexure-mounted system measuring $12^{3}/_{8}$ in. in length and $2^{1}/_{8}$ in. in diameter which has essentially no interaction.

On the basis of the results to date in the Southern California Cooperative Wind Tunnel, the balance has been found to provide the desired degree of accuracy and repeatability. Mr. Fellers supplemented his lecture with slides showing the design development and test results. The lecture was followed by a period of discussion and inspection of the balance system.

Montreal Section

G. E. Otter, *Secretary*

The Montreal Section held an organization dinner meeting in the International Aviation Building on October 26. Fifty-five members and guests attended the meeting.

A survey of I.A.S. members residing in the Montreal area had encouraged a Steering Committee to proceed with the organization of this Section.

W. K. Ebel, I.A.S. Vice-President and Vice-President of Engineering, Canadair Limited, briefly outlined the history and aims of the I.A.S.

The following officers were elected for the 1950–1951 season: Chairman, J. W. R. Drummond, Supervisor, Sales Engineering, Canadian Pratt and Whitney Aircraft Company, Ltd.; Vice-Chairman, E. B. Schaefer, Chief Technical Engineer, Canadair Limited; Secretary, G. E. Otter, Technical Engineer, Canadair Limited; and Treasurer, W. B. Boggs, Assistant to Montreal Superintendent, Trans Canada Air Lines. The Advisory Board consists of W. K. Ebel; D. L. Mordel, Associate Professor of Mechanical Engineering and Director, Gas Dynamic Laboratory, McGill University; W. B. O'Neal, Chief of Design Sections, Canadair Limited; and H. V. Wright, President of Canadian Wright Limited.

Dr. D. C. MacPhail, Assistant Director, Mechanical Engineering Division, National Research Council, Ottawa, addressed the gathering on the subject of "Jets and Sprays." Dr. MacPhail covered the problems associated with proper atomization of liquids used in internal-combustion engines, gas-turbine engines, etc. Slides were shown, as well as an interesting film covering the experimental work carried out in the N.R.C. droplet wind tunnel.

New York Section

R. P. Harrington, *Secretary*

Willy Ley, Research Consultant, was the speaker at the first fall meeting of the New York Section held in the auditorium of the Engineering Societies Building on October 10. Chairman R. Dixon Speas presided at the meeting. About 150 persons attended.

"The Upper Atmosphere—Its Exploration and Exploitation" was the topic for Mr. Ley's talk. After giving an extensive review of the concept of the upper atmosphere for the past nine centuries, Mr. Ley then discussed in considerable detail the more recent findings. Since the war, extensive exploration was made possible by instrument-carrying rockets capable of reaching extremely high altitudes and has added much to our knowledge of the atmosphere. He

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pointed out that experimental findings at high altitudes agreed closely with those predicted for the standard N.A.C.A. altitude. He also added information regarding the mean free path of molecules and the temperatures encountered up to considerably above 100 miles. According to his reasoning, the practical altitude limit for propeller and turbojet-powered aircraft would be in the neighborhood of 70,000 ft. Rocket-powered aircraft would best be operated above 250,000-ft. altitude to eliminate drag effects resulting from their great speed.

A motion picture in color illustrating the use of the V-2 rocket in the upper-air research was presented. A general discussion followed the presentation.

Ottawa Aeronautical Society

J. C. Finlayson, *Secretary*

The October 30 meeting was held in the Lecture Hall of the National Museum, Ottawa. F. N. Piasecki, President, Piasecki Helicopter Corporation, was the speaker, and he gave a most interesting talk under the heading "Military Applications of Large Transport Helicopters." Mr. Piasecki outlined helicopter developments up to the present time, described the probable future trends, and gave a comprehensive outline as to how the transport helicopter fits into military operations. The speaker was introduced by the Society's Chairman, Air Marshal G. O. Johnson, and was thanked by H. S. Rees, Chief Aeronautical Engineer, Department of Transport, Canada.

Philadelphia Section

Dale Hamilton, *Secretary*

The following officers were introduced at the October 4 meeting: Chairman, Hugh Mulvey; Vice-Chairman, H. S. Campbell; Secretary, Dale Hamilton; and Treasurer, L. Cheeseman.

The meeting chairman, George Simpson, Naval Air Material Center, introduced the speaker, Vincent Moore, Manager, Design Division, Wright Aeronautical Corporation Division, Curtiss-Wright Corporation. Mr. Moore reviewed the development of various types of aircraft power plants. He pointed out that the reciprocating engine was a highly developed piece of machinery. He further stated that it had now reached the stage of diminishing returns for further development and that the next practical step was a completely new concept of engine development. It seems logical, he said, to follow the steam development, which went from the reciprocating engine to a turbine.

The turbine engine lends itself to component testing. The facilities of component testing of large engines must be extremely large and expensive. For example, for the 5,000-hp. engine, the compressor horsepower is approximately 15,000 and the turbine horsepower is 20,000. Another approach to this problem is the compounding of several smaller engines as was done with the Allison T38.

The propeller turbine is more efficient at high-burner temperatures, while the jet turbine is more efficient at lower burner temperatures and high mass flow. Therefore, the development of the turbine in the turboprop engine must be given special consideration. The ultimate aims for the turboprop engine are higher burner temperatures and higher compression ratios. With these developments not far off, it seems possible that specific fuel consumption can be brought below those of the piston and compound engines.

The control problem of turboprops is more complicated than that of the jet engine, because the propeller speed must also be taken into account.

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St. Louis Section

Jack A. Durand, *Secretary*

The first fall meeting was held on September 12 at the Institute of Technology Building at St. Louis University. David S. Lewis, Vice-Chairman, presided. The Secretary gave the minutes of the previous organizational meeting and the report of the meeting of the Officers, at which the Program and Membership Committees were appointed. Ben G. Bromberg, McDonnell Aircraft Corporation, and Dr. C. J. Kippenhan, Washington University, were designated Chairmen of the Program and Membership committees, respectively. A committee was appointed to investigate and decide upon a permanent meeting place.

The Program Committee presented its general outline for meetings in 1951. The programs, as outlined, will include presentation of technical papers by local members, talks by nationally prominent people, and an occasional field trip to a big industry in this district.

It was then decided to encourage student participation in the meetings by inviting them to attend the meetings and perhaps, in the future, sponsor a series of competitive paper presentations by Student Members.

Edward Flesh, of the Program Committee, then introduced the speaker of the evening, R. H. Belt, McDonnell Aircraft Corporation, who spoke on "Power Controls and Artificial Feel Systems." Mr. Belt gave a summary of control systems that were adequate enough at low speeds but that in high-speed flight gave rise to oscillations, flutter, and stick forces so that some artificial means to regulate the stick forces necessary to operate the control surfaces had to be devised. Mr. Belt presented slides and discussed various types of hydraulic, spring, and aerodynamic power-boost systems. A discussion period followed in which he answered many questions presented by the audience.

Following the talk, a Shell Oil Company film, *British Farnsworth Air Show*, was presented in which many of England's latest reciprocating-engine, jet-engine, and turboprop-engine aircraft were viewed. Sixty members attended the meeting.

San Diego Section

W. H. Shutts, *Secretary*

A dinner meeting was held on September 28 with 42 members and guests attending. Following the dinner, a short business meeting was held to announce the results of the annual election of new officers. Those elected are: Chairman, W. T. Immenschuh; Vice-Chairman, C. C. Love, Jr.; Treasurer, R. P. White; Corresponding Secretary, W. H. Shutts; and Recording Secretary, N. E. Maxwell.

The speaker of the evening was William C. Keller, Project Engineer, San Diego Division, Consolidated Vultee Aircraft Corporation, who presented a paper on "Propeller Turbines in Transport Aircraft."

Mr. Keller described the proposed installation of an Allison 501-A2 turboprop engine in the Convair 240 transport airplane. Computed flight performance data for the 240 with the turboprop engine as compared with a reciprocating-type engine of the same output showed significant improvement in take-off and altitude fall-off characteristics with an accompanying decrease in weight of about 1,400 lbs. It was estimated that the cost would be comparable on a production basis. Mr. Keller foresees a permanent place in the short-range transport field for the propeller-turbine-powered airplane.

An interesting discussion of the development and future possibilities of the turboprop engine followed Mr. Keller's talk.

▶ A successful forum on the subject of "Advances in Aircraft Instrumentation" was held by the Section at a dinner meeting on November 2 with 51 in attendance.

The panel speakers were: M. C. Brady, Research Engineer in Charge of Dynamics-Engineering Test Laboratory; R. A. Ackley, Research Group Engineer in Charge of Instrumentation Laboratory; H. K. Cheney, Chief of Missile Test; and W. W. Fox, Flight Project Engineer. All of the above are from Convair. K. R. Jackman, Chief of Convair's Engineering Test Laboratory, served as Moderator.

The discussion covered instrumentation of the Convair PB-5Y, measuring techniques as related to aircraft instrumentation, instrumentation utilized in dynamic testing, and missile instrumentation.

Toronto Section

H. C. Luttman, *Secretary*

On October 19, the first fall meeting was held at the University of Toronto and was addressed by F. R. Thurston, Structures Laboratory, National Research Council, Ottawa. About 45 members attended.

Mr. Thurston's subject was "Fatigue in Aircraft Structures" and was illustrated with slides. The speaker started by emphasizing the importance of fatigue investigation and stated that, although the record of fatal accidents due to fatigue failure was fairly good, maintenance records showed that a high proportion of minor trouble was attributable to this cause. It was a problem, therefore, which would require the development of good fatigue-resisting practice in detail design and in shop techniques. Although at present no government regulations cover the subject, I.C.A.O. has recently put out a recommendation that is a clear indication of the trend.

Mr. Thurston proceeded to point out that our understanding of fatigue both in materials and structures is extremely sketchy and that almost all our present theory is based upon "assumption piled upon empiricism."

He discussed S-N curves at some length and described some of the difficulties encountered in the compilation of reliable data from which such curves might be prepared and in the correlation of experimental results with full-scale practice. He touched upon the inadequacy of test equipment (e.g., the monitoring of tests by strain gages had proved impracticable because the gages themselves suffer from fatigue) and such features as size effect, rate of loading, temperature, relaxation periods, and finish, all of which render the problem a difficult one. Mr. Thurston also discussed the treatment of cumulative damage and the relation of cumulative damage to ultimate strength, concluding that this relationship seemed to be as indefinite as our other knowledge of fatigue phenomena. Incidentally, it was of interest to note that, in many of the curves shown on the screen, 75S-T showed a much lower endurance than 25S-T under fatigue-stress conditions.

The speaker made reference to this last point in summing up and emphasized that, although ultimate strengths of materials have increased enormously, resistance to fatigue has not; therefore, it is a matter of great importance that research into the problem be pressed forward and fatigue-consciousness be instilled into all who are concerned in the design and manufacture of aircraft.

Wichita Section

Melvin H. Snyder, Jr., *Secretary*

The officers of the Wichita Section for 1950–1951 are: Chairman, Douglas C. Heimburger; Vice-Chairman, Henry F. Waring, Jr.; Secretary, Melvin H. Snyder, Jr.; Treasurer, John Kintas.

Wichita's New Officers: *Shown at the October meeting of the Wichita Section are the 1950–1951 Officers and the Speaker of the Evening. From left to right, they are: Vice-Chairman, Henry Waring, Jr.; Program Chairman, Bill Pearce; Chairman, Douglas C. Heimburger; Speaker, T. H. McNary; Treasurer, John Kintas; and Secretary, Melvin H. Snyder, Jr.*

The new Chairman, Doug Heimburger, was a test pilot in the development program of the YL-15 and is now at Boeing-Wichita's Flight Test Section where he is a test pilot of the Boeing B-47 jet bomber.

Hank Waring is Engineering Pilot for the Cessna Aircraft Company. Mel Snyder is Acting Head, Aeronautical Engineering Department, School of Engineering, University of Wichita, where he is faculty sponsor of the I.A.S. Student Branch. John Kintas is in the Aerodynamics Section, Beech Aircraft Corporation.

A dinner meeting held in the Shirkmere Hotel on October 12 was followed by a technical paper delivered by T. H. McNary, Chief, Electric Staff Group, Wichita Division, Boeing Airplane Company. Mr. McNary spoke on the subject of "Application of Electronics in Aviation." The talk included a summary of the fundamentals of electronics and illustrations of specific examples in the V.O.R., Omnirange, and D.M.E. systems of flight navigation.

Student Branches

Academy of Aeronautics

Three films were shown at the October 10 meeting at which Chairman James Sneden presided. The first movie, *The Story of the Flying Wing*, was obtained from Northrop Aircraft, Inc., and dealt with the design and development of the Flying Wing. The second picture, *A Thunderbolt Is Made*, showed the F-47 Thunderbolt from raw materials to finished product. The third film was *Pratt & Whitney Water Injection*, and it demonstrated the advantages of water injection as applied to military aircraft for extra power boost in time of emergency. Forty persons attended the meeting.

Cal-Aero Technical Institute

Election of officers was held on September 12 with the following results: Chairman, W. W. Lee; Vice-Chairman, James Spriggs; and Secretary-Treasurer, Charles Reid.

The September 20 meeting was opened by outgoing Chairman John U. Sweeney. The speaker, Sergeant Clark of the Glendale Recruiting Service, spoke on the benefits of an enlistment in the U.S.A.F. The new officers were then introduced, and incoming Chairman W. W. Lee adjourned the meeting.

California State Polytechnic College

A film, *Fortress of the Sky*, distributed by Boeing Airplane Company, was shown at the September 28 meeting. Chairman Milo V. Price presided; 25 members and 16 guests attended.

On October 12, Hugh Haroldson, Instructor, Mechanical Engineering Department, C.S.P.C., spoke to the 31 members and 13 guests on "The Texaco Combustion Process." He discussed the new combustion chamber developed by The Texas Company at their Beacon (N.Y.) Laboratories. Two films that were obtained from Northrop Aircraft, Inc. (*Miscellaneous Views of All-Wing Aircraft* and *The Northrop Supersonic Rocket Sled*), were shown. Chairman Price presided.

The Catholic University of America

The October 4 meeting was called to order by Chairman Charles J. Carney. Two films, *N.A.C.A. Research* and *Ames Laboratory in Action*, were shown. Twenty-two members attended.

University of Cincinnati

The film, *Wind Tunnels of A.M.C.*, was shown at the September 29 meeting. The picture demonstrated and explained the various wind tunnels in use at the Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio, as well as tests typifying those conducted in the tunnels. The meeting, with an attendance of 25, was led by Chairman Dale A. Benethum.

Clarkson College of Technology

Two films, *Wright Builds for Air Supremacy* and *PBM-3 Wing Destruction Test*, were shown at the October 18 meeting. The former was concerned with the development of the Wright engine; the latter demonstrated the testing of the PBM-3 wing structurally from conception to completion. Chairman Robert H. Waters presided. Fourteen persons attended the meeting.

A color sound film, *N.A.C.A. Research*, which gave a general view of research as conducted in the N.A.C.A. laboratories, was shown to the 18 persons attending the November 1 meeting. Chairman Robert C. Waters presided.

University of Detroit

New officers were installed at the September 28 meeting. They included: Chairman, Donald R. Lap-

UNIVERSITY OF SOUTHERN CALIFORNIA

The Faculty Adviser and recently elected Student Branch Officers are shown in the accompanying picture. From left to right, they are: Faculty Adviser, Prof. James B. Vernon; Chairman, Theodore R. Metz; Secretary, Samuel G. Hansen; Treasurer, Norbert B. Vaughn; and Vice-Chairman, George S. Metteer.

worth; Vice-Chairman, Richard Cass; Treasurer, Richard T. Robinette; and Secretary, Thomas E. Stuck. Joseph Conway and Thomas Hurst were designated the Senior and Junior Representatives to the Student Council.

A film, *Super-Sonic Flow*, as studied at the University of Michigan, was shown to the 20 attending members. Chairman Donald Lapworth led the meeting.

Louisiana State University

Two films were shown at the conclusion of the October 20 meeting at which Chairman Robert Dawson presided. The pictures were loaned by the McDonnell Aircraft Corporation and were *Little Henry* and *X HJD-1*.

Massachusetts Institute of Technology

Two films, *Jet Getaway* and *Farnborough Air Show*, were shown at the October 17 meeting. The former was concerned with pilot ejection from fast jets and the latter with the 1949 British S.B.A.C. show.

North Carolina State College

Speaker at the October 17 meeting was Major G. E. Lundquist, U.S.A.F., who is attending N.C. State College as a graduate student in Nuclear Engineering. Major Lundquist spoke on his experiences while flying the Bell XS-1.

North Dakota Agricultural College

A film shown at the September 21 meeting was entitled *Flight Log*. It was produced by the Shell Oil Company and demonstrated their part in the development of high-octane, antiknock gasoline.

Officers for the 1950–1951 school year are: Chairman, Donald Trett; Vice-Chairman, Robert Flynn; Secretary, James Marquardt; and Treasurer, Arthur Stennes.

The Ohio State University

Elections for the 1950–1951 officers resulted in the following: Chairman, Lee V. Gossick; Vice-Chairman, Robert Heninger; Secretary, Richard H. Miller; and Treasurer, David Ulry.

The University of Oklahoma

The October 11 meeting was opened by Chairman Harold G. Coles, Jr. A film, *Introduction to Radar*, was shown to the 20 persons attending.

Riddle McKay College of Aeronautics

Boyd Stevens, Assistant Engineering Superintendent, Pan American World Airways, Inc., Miami, spoke at the October 12 meeting on "What an Airline Is." The lecture was followed by a tour of Pan American's overhaul shop and terminal. Chairman Joseph W. Justin presided.

On October 30, two films, *Power by Wright* and *Altitude Gyro*, were shown. Secretary Donald E. Morgan tendered his resignation. Chairman Justin presided and 75 persons attended.

Spartan College of Aeronautical Engineering

At the October 3 meeting, Leroy Keely and Aldon Fisher were elected Corresponding Secretary and General Secretary, respectively. Chairman James M. Mahaffey presided; 30 persons attended.

Syracuse University

Professor Leslie R. Parkinson, Chairman, Departments of Aeronautical and Mechanical Engineering, College of Applied Science, Syracuse University, was the speaker at the October 18 meeting. His subject was "The N.A.C.A. Research and Development Board." Chairman George Schmanke presided and 16 persons attended.

The November 1 meeting was opened by Vice-Chairman Hal Stewart. Jack Andrews, 138th National Guard Fighter Group, spoke on "The Pilot and the Military Airplane."

Three films shown were *Airplane Structures; Aerodynamics: Lift;* and *Aerodynamics: Air Resistance and Streamlining.*

University of Toronto

The following officers were elected for the 1950–1951 season: Chairman, S. Timoshek; Vice-Chairman, J. E. Topping; and Secretary-Treasurer, J. J. L. Adams.

University of Tulsa

The October 5 meeting was called to order by John Beadling, the 1949–1950 Vice-Chairman, and elections were held. The results were: Chairman, John Beadling; Vice-Chairman, Owen Anderson; and Secretary-Treasurer, William S. Jones.

University of Wichita

At the October 19 meeting, Chairman Robert Foster introduced Prof. Kenneth Razak, Acting Dean, College of Business Administration and Industry, University of Wichita, who delivered a paper on "Boundary-Layer Control." Professor Razak summarized the various methods proposed for control of the boundary layer and for increasing the maximum lift coefficient of airfoils. He presented the basic theories regarding boundary-layer control and talked of some of the work being conducted in the wind-tunnel research program at the University of Wichita under the sponsorship of the Office of Naval Research.

THE BANSHEE
HOLLEY

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Halpert, Percy, E.E., Engineering Dept. Head for Flight Controls, Sperry Gyroscope Co. Div., The Sperry Corp.

Transferred to Associate Fellow Grade

Heath, William C., Chief Engineer & Manager of the Engineering Div., Solar Aircraft Co.

Saksena, Gajraj B., M.Sc., Asst. Chief Stressman, Messrs. de Havilland Propellers, Ltd.

Elected to MEMBER Grade

Algeri, Dante J., M.Sc., Instructor, Walter Hervey Junior College.

Ayers, Kenneth B., B.Sc., Sr. Asst. Lecturer, Aircraft Design, Loughborough Engineering College.

Beach, C. J., B.S., Technical Asst., British Overseas Airways Corp.

Bellman, Donald R., M.S. in M.E., Aero. Research Scientist—Research Staff Engineer, N.A.C.A. (Muroc).

Budish, Nathan N., B.Ae.E., Sr. Aerodynamicist, Boeing Airplane Co. (Seattle).

Danforth, Clarence E., S.B., Stress Vibration Analyst, Turbine Component Section, General Electric Co. (Lynn).

Engelbrecht, Alfred E., Ph.D., Vibration Engineer, North American Aviation, Inc.

Faught, Harold F., B.M.E., Thermodynamicist, Westinghouse Electric Corp.

Kurzweg, Hermann H., Ph.D., Chief, Aeroballistics Div., Naval Ordnance Lab. (White Oak).

Lowy, Mortimer J., B.S., Stress Analyst, Douglas Aircraft Co., Inc. (Long Beach).

Meschino, Ronald G., B.Sc. (M.E.), Design and Development, Self-Employed.

Potts, Robert G., B.S., Experimental Test Engineer, Propeller Div., Curtiss-Wright Corp.

Schimoler, John J., B.E.E., Section Engineer, Design Group, General Electric Co. (West Lynn).

Smeltzer, Sterling B., A.B., Chief Service Engineer, Curtiss-Wright Corp.

Sokoloff, David, B. of M.E., Aerodynamicist, North American Aviation, Inc.

Stouffer, John W., Asst. to the Project Engineer in Charge of Testing, Marquardt Aircraft Co.

Strough, Robert I., Ph.D., Project Engineer, Analytical Group, Pratt & Whitney Aircraft Div., United Aircraft Corp.

Talmage, Donald B., A.B., Aero. Research Scientist & Member, Hq. Technical Staff, N.A.C.A. (Washington, D.C.).

Tracy, Alfred C., B.A. (Physics), Dynamics Engineer, Douglas Aircraft Co., Inc.

Virgin, Edward W., B.S. in M.E., Eastern Representative, North American Aviation, Inc.

Transferred to MEMBER Grade

Baker, Marvin E., Capt. U.S.A.F.; Asst. Chief, Equipment Branch, Hq., Air Materiel Command, Wright-Patterson Air Force Base.

Boswell, Clay C., Jr., M.S. in Ae.E., Structures Engineer "A," Hughes Aircraft Co.

Curry, Warren H., M.S., Research Assoc., Dept. of Engineering Research, Willow Run Research Center.

High, John Richard, B.S. in Ae.E., Lt. (j.g.), U.S.N.; Student in Ordnance Engineering, U.S. Naval Postgraduate School (Annapolis).

Kriegsmann, Elizabeth M., B.Ae.E., Aero. Research, Development & Design Engineer P-2, Engineering Div., Hq., Air Materiel Command, Wright-Patterson Air Force Base.

Nitikman, Herschel, M.S. in Ae.E., Aerodynamicist, Northrop Aircraft, Inc.

Peterson, Norman C., Ph.D., Chief, Aerodynamics Research Group, Aircraft Div., The RAND Corp.

Robinson, John S., A.E., Engineer-Designer "B," Consolidated Vultee Aircraft Corp. (Ft. Worth).

Strong, Edward W., B.S. in Ae.E., Missile Project Aerodynamicist, Grumman Aircraft Engineering Corp.

Elected to Associate Member Grade

Brophy, Gerald B., LL.B., Partner, Chadbourne, Parke, Whiteside, Wolff & Brophy.

Elected to Technical Member Grade

Behmoiras, Jacques, Chief Project Engineer, Israel Air Force.

Blout, Clayton C., B.S. in M.E., Handbook Editor, U.S.A.F. (St. Louis).

Goldman, Bernard, M.S., Technical Editor, Specifications Group, Bell Aircraft Corp.

Handforth, Gordon W., Designing Draughtsman, A. V. Roe Canada Ltd.

Katten, Stanley L., B.S. in M.E., Project Engineer, ITE Circuit Breaker Co.

Nankey, Ralph W., B.S., Helicopter Engineer, Bell Aircraft Corp.

Shapiro, Norman M., B.S., Physicist GS-7, Naval Ordnance Lab. (White Oak).

Transferred to Technical Member Grade

Aass, Haakon, B.A.Sc., Lt. & Technical Educational Officer, Royal Norwegian Air Force.

Adams, Earl W., B.S. in Ae.E., Engineering Draftsman "B," Air Conditioning Group, Douglas Aircraft Co., Inc. (El Segundo).

Adams, Gordon S., B.S., Lt. & Student, Radar Fundamentals, U.S.A.F. (Keesler Air Force Base).

Akin, Phillip, B.S., Graduate Student, Stanford University.

Baber, Hal T., Jr., B.S. in Ae.E.

Baca, Arthur F., B.S. (Aero.), Jr. Engineer (Structures), Consolidated Vultee Aircraft Corp. (San Diego).

Bauer, Elmer M., B.S., Vibration & Flutter Engineer, Research Group, Grumman Aircraft Engineering Corp.

Becker, Marshall E., Template Layout, Piasecki Helicopter Corp.

Bekkedahl, James L., B.Ae.E., Aerodynamicist, Douglas Aircraft Co., Inc. (Long Beach).

Bethel, Roy P., B.S. in Ae.E., Aero. Engineer GS-5, U.S. Army Air Base, (McClellan Field).

Brindle, Clayton C., B. of Ae.E., Ramp Attendant—Cargo, Capitol Airlines (Washington, D.C.).

Bussink, Frances A., B.S. in M.E. (Aero.).

Butterfield, Roy G., B.S., Engineer, Bendix Products Div., Bendix Aviation Corp.

Carr, Robert W., B.S., Experimental Asst., NEPA Div., Fairchild Engine and Airplane Corp.

Charhut, Frank J., B.S. in Ae.E., Designer-Draftsman, Allis Seal Corp.

Chilton, James P., B.E., Mathematician "A," Aerodynamics Group, Douglas Aircraft Co., Inc. (Long Beach).

Corcoran, Edward L., B.S., Capt. & Pilot, U.S.A.F.

Crandall, Richard R., B.S., Trainee Engineer, Diesel Div., General Motors Corp.

Crim, Harry C., Jr., B.M.E., Major & Staff Armament Officer, U.S.A.F. (Langley Air Force Base).

Cross, Norman L., B.S. in Ae.E., Senior Detailer, Test Equipment, Allison Div., General Motors Corp.

Dahlstrom, Norman R., B.A.E., Test Engineer, Blade Group, Hamilton Standard Div., United Aircraft Corp.

Daly, Robert E.

DeBrakeleer, Henry J., A.A. in Ae.E., Draftsman, Goodyear Aircraft Corp.

De Groote, Raymond S., B.S., Naval Aviator, U.S.N.

Del Pup, Lydio.

Douvillier, Joseph G., Jr., B.S. in M.E., Aero. Engineer GS-5, U.S.A.F., Air Materiel Command, Wright-Patterson Air Force Base.

Duncan, Roger M., B.S. in M.E., Engineer, Experimental Dynamometer Lab., White Motor Co.

Dunlap, Donald S., B.S. in Education, Col., U.S.A.F.

Eastman, Gunnstein V., B.A.Sc. in Ae.E., Engineer, Design Office (Electrical Group), A. V. Roe Canada Ltd.

Edighoffer, Harold H., B.S., Engineering Draftsman "B," Fuselage Dept., Consolidated Vultee Aircraft Corp. (Ft. Worth).

Ekern, Harold O., B.Ae.E., Student Officer—Pilot Training, U.S.A.F., Randolph Air Force Base.

Falbo, Theodore, B.S. in Ae.E., Mathematician, Guided Missiles Group, Douglas Aircraft Co., Inc. (Santa Monica).

Ferenc, Adam J., B.Ae.E., Design Engineer, A. V. Roe Canada Ltd.

Fey, Wayne, M. of Eng., Assoc. Engineer, Applied Physics Lab., The Johns Hopkins University.

Fletcher, John F., Col., U.S.A.F.; Asst. Director of Maintenance, Continental Air Command (Mitchell Air Force Base).

Flynn, James C., B.S.M.E., Major, U.S.A.F.; Asst. Chief, Missiles Engines Unit, Rotating Engine Branch, Power Plant Lab., Air Materiel Command, Wright-Patterson Air Force Base.

Forrest, Richard L., B. of A.E., Technical Engineer, Engine Lab. Section, Aircraft Gas Turbine Div., General Electric Co.

Fosdick, George E., M.S. in Ae.E., Jr. Aerodynamicist Engineer, Wind Tunnel Test Group, The Glenn L. Martin Co.

Fowler, Carl A., Jr., B.S. in Ae.E., Liaison Engineer, Boeing Airplane Co. (Wichita).

Fox, Richard J., B.S. in Ae.E.

French, Charles E., Jr., B.S., Aircraft Adjuster Trainee, General Adjustment Bureau (San Francisco).

Gadbery, Earl L., B.S.Ae.E., Sales Engineer, Aluminum Co. of America.

Garwood, LeRoy E., Master Layout "A," Tooling Dept., Douglas Aircraft Co., Inc. (El Segundo).

Gentemann, Arthur J., B.S., Jr. Engineer, Boeing Airplane Co. (Seattle).

Goldstein, David S., B. of Ae.E., Jr. Engineer "B," Boeing Airplane Co. (Seattle).

Goss, Quentin J., B.S., Capt., U.S.A.F.; Assigned to Special Weapons Section, Northrop Aircraft, Inc.

Groesbeck, William A., B.Ae.E., Graduate Student, University of Minnesota.

Gugleta, Stephen L., B.S. in Ae.E., Stress Analyst, Goodyear Aircraft Corp.

Hamilton, Thomas M., Draftsman, William R. Whittaker Co.

Harmon, Thomas M., B.Ae.E., Instrumentation Engineer, Grumman Aircraft Engineering Corp.

Hawkins, James C., Jr., B.S.

Healy, Bradford C., B.Ae.E., 1st Lt. & Aircraft Navigator, U.S.A.F.

Higby, William W., B.S. in Ae.E., Jr. Engineer "B," Structures Section, Body & Wing Group, Boeing Airplane Co. (Seattle).

Highley, Frank M., Jr., Jr. Engineer, Scheduling Group, Piasecki Helicopter Corp.

Hile, Edwin E., B.S., Engineering Designer "A," Consolidated Vultee Aircraft Corp. (Ft. Worth).

Hoffer, John R., B.Ae.E.

Horton, William P., B.S., Test Engineer, General Electric Co. (Lockland, Ohio).

Hughes, James E., B.S., Lt., U.S.A.F.; Project Officer, Research & Development of Airborne Electronics, Wright-Patterson Air Force Base.

Humenick, William, M.S. in Ae.E., Research Engineer, Marquardt Aircraft Co.

Imgram, Donald A., B. of Ae.E., Design Engineer, Pilotless Aircraft Dept., Grumman Aircraft Engineering Corp.

Jerahian, George K.

Jillie, Don W., B.S., Draftsman "A," Douglas Aircraft Co., Inc. (Long Beach).

Johnson, Marvin C., B.Ae.E., Graduate Student, University of Minnesota.

Johnson, Merle B., Design Detail Draftsman, Aerojet Engineering Corp.

Joslyn, Warren A., A.E., Jr. Engineer, Stress Unit, Boeing Airplane Co. (Seattle).

Keough, James B., B.S.Ae.E. (Engines), Lab. Asst., Allison Div., General Motors Corp.

Koblish, Theodore R., B.A.E., Engineer, Robert Reichhelm Co., Inc.

Kueser, Paul E., B.S.Ae.E., Ensign, U.S.N.; Line Officer, U.S.S. "Higbee."

Kuhn, Robert B., B.S., Major, U.S.A.F.; Design & Development Officer, Bombardment Branch, Engineering Div., Air Materiel Command, Wright-Patterson Air Force Base.

La Forge, Sally, B.S. in M.E., Engineering Draftsman "B," Hughes Aircraft Co.

LaMont, Charles W., B.S. in Ae.E., Stress Analyst & Jr. Engineer, Propeller Div., Curtiss-Wright Corp.

Lane, Archie G., Wind Tunnel Operator, Southern California Cooperative Wind Tunnel.

Leak, Arthur B., B.Ae.E., Graduate Student and Asst., California Institute of Technology.

Lee, Alan C., B.S., Design Engineer "B," Power Plant Group, Douglas Aircraft Co., Inc. (Long Beach).

Lee, Alan H., Jr. Engineer "B," Boeing Airplane Co. (Seattle).

Lees, John R., B.Ae.E., Engineer, Ex-Cell-O Corp.

Loomis, Ralph W., B.S.E. in Math., Mathematician, Naval Ordnance Plant (Indianapolis).

Lowry, Robert E., B.S., Engineer, Minneapolis-Honeywell Regulator Co.

Lundquist, Leslie E., M.S.Ae.E., Aerodynamicist "B," Douglas Aircraft Co., Inc. (Santa Monica).

Macomb, James T., Weights Engineer, Sikorsky Aircraft Div., United Aircraft Corp.

Marshall, Allen H., B.S., Jr. Engineer Boeing Airplane Co. (Seattle).

McKinley, Phil, B.S. in M.E. (Aero.), Engineering Draftsman "B," Lockheed Aircraft Corp.

Meholick, William N., B.S.Ae.E., Stress Analyst, Grumman Aircraft Engineering Corp.

Mikami, Kinya, B.S.E. in Ae.E.

Mooney, Walter E., B.A., Aero. Engineer, Helio Aircraft Corp.

Mosher, David A., A.A. in Ae.E., Aircraft Assembler, Boeing Airplane Co. (Wichita).

Moszer, Sidney, Structural Engineer, Sikorsky Aircraft Div., United Aircraft Corp.

Myers, Robert L., B. of Ae.E., Capt. and Pilot, U.S.A.F. (Selfridge Air Force Base).

Nadler, Paul O., B.S.A.E., Capt. and Senior Pilot, U.S.A.F.

Nagle, Omar R., Jr., B.S., Jr. Engineer, Change Group, Boeing Airplane Co. (Seattle).

Naticone, Luigi D., B.S.

Nerenstein, Wilbur, B.S.

Pearson, Merwin D., B.S. in Ae.E., Aero. Research Scientist, N.A.C.A. (Langley Air Force Base).

Peterson, Edward H., 1st Lt., U.S.A.F. (Keesler Air Force Base).

Piper, Earl M., B.S.E. (Aero.), Jr. Engineer, Boeing Airplane Co. (Seattle).

Porter, Fletcher S., Capt., U.S.A.F.; Asst. Professor of Air Sciences & Tactics, Air R.O.T.C. Unit, Alabama Polytechnic Institute.

Power, Donald E., Senior Draftsman, Goodyear Aircraft Corp.

Prach, Harold J., A.A. in Ae.E., Jr. Designer, Goodyear Aircraft Corp.

Priestley, R. Thomas, B.S., Research Engineer, Naval Supersonic Lab., Massachusetts Institute of Technology.

Prince, Loyd B., B.S.Ae.E.

Priser, Jacob W., B.S., Engineering Draftsman—Production Design, The Glenn L. Martin Co.

Rall, Fred T., S.B. in Ae.E., Project Engineer, Southern California Cooperative Wind Tunnel.

Reynolds, Joe D., Draftsman, Beech Aircraft Corp.

Reynolds, William N., Jr., B.S. in Ae.E., Flight Line Mechanic, North American Aviation, Inc.

Richards, Donald W., B.S. in M.E. (Aero.), Sr. Draftsman, Goodyear Aircraft Corp.

Richardson, Ross, A.A. in Ae.E., Draftsman, Radio & Radar Section, A. V. Roe Canada Ltd.

Robinson, Glenn H., B.S. in Ae.E., Mathematician, Structures Test, North American Aviation, Inc.

Rogers, Basil B., B.S. in Ae.E., Jr. Engineer, Boeing Airplane Co. (Seattle).

Russo, Joseph E., Capt. and Pilot, U.S.A.F.; Asst. Chief, Production Inspection Section (Olmstead Air Force Base).

Sahaida, George, B. of Ae.E., Liaison Engineer, Boeing Airplane Co. (Seattle).

Scandalis, Angelo C., B.A.E., Tool Designer, Liberty Aircraft Products.

Schneider, LeRoy J., B.S. in Ae.E., Master Layout—Tooling, Douglas Aircraft Co., Inc. (El Segundo).

Scholz, Edward R., Line Mechanic, Continental Airlines (Stapleton Field).

Schroeder, Henry B., B.Ae.E., Jr. Engineer, Flight Test Group, Piasecki Helicopter Corp.

Schuster, Robert R., B. S. in M.E. (Aero.), Engineering Draftsman "B," Lockheed Aircraft Corp.

Schwartz, Martin D., Sc.D. in Ae.E., Sr. Engineer and Project Leader, Research Lab., Massachusetts Institute of Technology.

Shea, James H., Lt. Col., U.S.A.F.; Chief, Gunnery Components Branch, Armament Lab., Hq., Air Materiel Command, Wright-Patterson Air Force Base.

Shockey, Thomas R., B.S., Draftsman, Cessna Aircraft Co.

Shostak, Adam, B.S.Ae.E.

Shultz, Albert B., Draftsman, Consolidated Vultee Aircraft Corp. (Ft. Worth).

Singletary, Norman E., B. of Ae.E.

Sladek, Richard R., B.S., Aircraft Loftsman & Wind Tunnel Model Designer, Chance Vought Aircraft Div., United Aircraft Corp. (Dallas).

Smillie, Donald G., B.S.Ae.E., Engineering Draftsman, Douglas Aircraft Co., Inc. (El Segundo).

Smith, Douglas R., B.S. (Mining Engineering), Major, U.S.A.F.

Smith, Joanna R., B.S.M.E. (Aero.), Jr. Structures Engineer, The Glenn L. Martin Co.

Smith, John W., B.S., Design Draftsman, Douglas Aircraft Co., Inc. (Long Beach).

Smith, Ronald K., B.S. in Ae.E., Engineering Draftsman, Cessna Aircraft Co.

Snow, Ralph H., S.B., Engineering Draftsman "B," Consolidated Vultee Aircraft Corp. (Ft. Worth).

Speaker, Ward V., B.S., Design Draftsman, Douglas Aircraft Co., Inc. (Long Beach).

Stauffenberg, Malcolm E., B.S.A.E., Jr. Engineer, Wright Aero. Corp. Div., Curtiss-Wright Corp.

Stephenson, Floyd E., Jr., B.A.E., Draftsman "B," North American Aviation, Inc.

Stewart, Douglas H., B.M.E.

Stilley, Donald, B.S., Graduate Student, Iowa State College.

Sturges, S. R., B.S. in M.E. (Aero.), Capt., U.S.A.F.; Testing & Project Officer, Air Proving Ground Command, Eglin Air Force Base.

Sutherland, Alexander E., B.A.Sc. in Ae.E., Flying and Jr. Engineering Officer, Royal Canadian Air Force.

Sutton, James R., B.S.Ae.E., Engineering Designer "B," Douglas Aircraft Co., Inc. (Long Beach).

Sweida, L. J., B.S.Ae.E., Engineering Draftsman, Douglas Aircraft Co., Inc. (Santa Monica).

Teigen, Mary J., B. of Ae.E., Asst. Scientist, Dept. of Aero. Engineering, University of Minnesota.

Thomas, Arthur N., Jr., M.S.Ae.E., Engineer, Aerophysics Section, Marquardt Aircraft Co.

Toth, Joseph, Engineering Draftsman, North American Aviation, Inc.

Tribolet, Robert W., B.S. (Military Engineering), Lt., Pilot and Engineering Officer, U.S.A.F.

Trustin, Yale F., B.S., Lt., U.S.A.F.; Asst. to Chief, Programs Monitoring Officer, Air Installations, Hq., Air Materiel Command, Wright-Patterson Air Force Base.

Turner, Edward C., B.S. in Ae.E., Engineering Draftsman (Electronics—Guided Missiles), Bell Aircraft Corp.

Van Aken, Ray W., B.E. (M.E.), Graduate Student, University of Southern California.

Vierra, Arthur K., Draftsman, Production Dept., William R. Whittaker Co.

Walker, Bruce R., Wind Tunnel Operator, California Institute of Technology.

Walters, William H., B.S., Capt. and Pilot, U.S.A.F.; Project Engineer, Wright-Patterson Air Force Base.

Ward, Edward A., B.S.Ae.E., Graduate Student, Cornell University.

Ward, Robert H., B. in Ae.E., Jr. Aerodynamicist, Chase Aircraft Co., Inc.

Wardein, John L., B.S. in Aero., Aero. Engineer, Loads Group, McDonnell Aircraft Corp.

Warren, Walter R., Jr., B.Ae.E., Graduate Asst., Navy Research—Project SQUID, Princeton University.

Wayne, James C., B.S. (Military Science & Engineering), 1st Lt. and Pilot, U.S.A.F.

Weil, Ernest A., B.A.E., Design Engineer, Teleflex, Inc.

Wente, H. A., B.S.A.E.

Wolansky, John, M.S., Research Assoc., Aero. Engineering Dept., Ohio State University.

Wolf, Harold J., Major & Pilot, U.S.A.F.

Woodard, Raymond C., B.S. in Ae.E., Aviation Metalsmith, O. & R. Dept., Naval Air Station (Norfolk).

Woodford, Philip R., B.M.E., Products Engineer, Lord Mfg. Co.

Woodring, Diedrich F., B.Ae.E., Draftsman "A," Wing Design Group, Douglas Aircraft Co., Inc. (Long Beach).

Wright, Dean E., Jr., B.Ae.E., Graduate Student, Rensselaer Polytechnic Institute.

Wright, John, B. of Ae.E., Asst. Project Engineer, Flight Test, Naval Air Test Center.

Wronski, William R., B.Ae.E.

Xenakis, George, B.S.

Young, Kenneth A., B.S. in Ae.E., Design Draftsman, Goodyear Aircraft Corp.

Young, Louis, S.B., Engineering Technician, Lockheed Aircraft Corp.

I.A.S. National Meeting Schedule

Nineteenth Annual Meeting—Hotel Astor, New York, January 29–31, February 1, 1951

Sixth Annual Flight Propulsion Meeting—Hotel Carter, Cleveland—March 16, 1951

Members or organizations wishing to submit papers for presentation at National Meetings should send outlines or summaries to the Committee no later than 5 months prior to the meeting.

All papers submitted will be considered for publication in the *Journal of the Aeronautical Sciences* or the *Aeronautical Engineering Review*.

All correspondence should be addressed to:

The Meetings Committee, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

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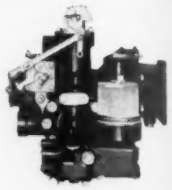

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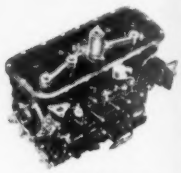

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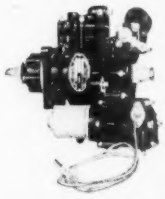

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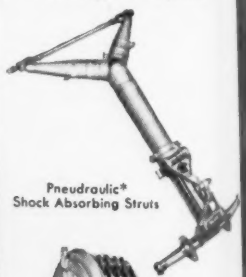

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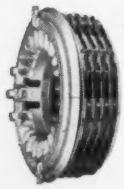

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Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

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Helicopter **Engineers**—For work in expanding research and development program. Design Engineers, Vibration Analysts (with flight-test experience), Electronic Engineers (with strain-gage-instrumentation experience), and Test Pilot (with engineering background). Minimum of 5 years' experience. American Helicopter Co., Inc., Manhattan Beach, Calif.

Aeronautical, Electrical, Electronic, and Metallurgical Engineers and Aeronautical Draftsmen—The Naval Air Station, Corpus Christi, Tex., is seeking engineers in several fields for present needs and probable future needs. Applications are desired from personnel who have training and experience in the fields of engineering described below. Applications for the positions should be made on Standard Form 57 available at any first- or second-class post office and should be mailed to Industrial Relations Officer, Naval Air Station, Corpus Christi, Tex. **Aeronautical Engineer**—Development of assigned prototypes and pilot installations of recently developed equipment; preparation of reports; analysis of discrepancies toward the development of repair methods; and the development of testing and/or adjustment procedures for aircraft components and accessories. Two (2) positions, grade GS-9, at $4,600 per year are open for immediate needs. **Metallurgical Engineer**—To make physical and metallurgical tests of metals; perform chemical analyses for determination of type; prepare reports and memoranda; develop procedure for plating and cleaning of metals; and make analyses of plating and cleaning vat solutions. One (1) position, grade GS-9, at $4,600 per year is open for immediate needs. **Electrical and Electronic Engineers**—To develop prototypes and pilot installations of recently developed electrical and electronics equipment; evaluate and analyze resulting test data; prepare reports; analyze known discrepancies and design repair methods; and develop testing and adjusting procedures. **Engineering Draftsmen**—To make detail and installation drawings from prototype parts on installations; make sketches from the engineers' descriptions; and do art work on photographs for clarification and identification. Several positions, ranging from grade GS-4 at $2,875 per year to GS-7 at $3,825 per year, are proposed.

Aeronautical Engineers—Senior, Intermediate, and Junior level; for participation in the design and application of rotary wing to convertible aircraft. This is your opportunity to become affiliated with a cooperative aviation concern. Inquiries welcomed from Aeronautical, Mechanical, Stress, and Power-Plant Engineers; Detail and Layout Draftsmen. Experience in helicopter field desirable. Salaries will be commensurate with qualifications and are part cash, part stock. Apply in writing with résumé of experience and education to: H. Peitzer, Gyrodyne Company of America, Inc., Fitzmaurice Field, Massapequa Park, L.I., N.Y.

Engineers—The following vacancies for engineering personnel exist in the Bureau of Aeronautics, Department of the Navy, Washington, D.C.: **Aeronautical Engineers**—GS-11, $5,400 per annum. PP-65, conservation and substitution of critical materials; testing for prevention of engine corrosion; specifications and standards for power transmission devices and gearboxes. PP-61, developmental programs and correction of defects in aircraft starters and auxiliary power plants. PP-66, maintain continuous engineering appraisal of engines assigned, administer flight and laboratory tests, and take appropriate corrective action. PP-67, evaluate designs, administer ground and flight tests, and maintain technical administration of research and development contracts for ram-jet and pulse-jet engines. PP-59, assist in development, testing, and determination of operating limits for reciprocating and turboprop engines and individual components thereof. **Metallurgist**—GS-12, $6,400 per annum. Conceive, plan, and supervise research, investigation, and development work in the light alloys used in naval aircraft. **Aircraft Structural Loads Engineer**—GS-11, $5,400 per annum. Review and evaluate structural air-load reports, specify a series of structural flight tests, and investigate structural problems arising during development or testing of airplanes or guided missiles. **Mechanical Engineer**—GS-9, $4,600 per annum. Develop and improve existing equipment and review proposals for new catapult deck equipment such as equipment for handling, positioning, and securing aircraft. **Aircraft Preliminary Design Engineer**—GS-12, $6,400 per annum. Initiate and develop general designs of subsonic and supersonic land- and carrier-based piloted and pilotless planes. **Supervisory Chemical Engineer**—GS-13, $7,600 per annum. Initiate, supervise, and coordinate research and development projects directed toward new and improved solid and liquid rocket fuels and oxidizers. **Supervising Aeronautical Rocket Power-Plant Development Engineer**—GS-13, $7,600 per annum. Head of the Rocket Engine and Component Section Development Section, which initiates, supervises, and coordinates developmental projects of new and improved rocket engines and components. **Aeronautical Rocket Power-Plant Development Engineer (Installations)**—GS-12, $6,400 per annum. Head of the Guided Missiles Application Unit, which plans, initiates, and supervises the design, arrangement, and installation features of rocket-engine systems. **Materials Engineer**—GS-11, $5,400 per annum. Designs and improves pilots' clothing, parachutes, safety harnesses, survival equipment, life rafts, galley equipment, and related aircraft equipment. **Aeronautical Engineer**—GS-11, $5,400 per annum. Research, design, and development of power-boost and power-operated flight-control systems and components thereof. **Fire Control Design Engineer**—GS-11, $5,400 per annum. Assists project engineer in carrying out programs for the development of systems and components for the control of aircraft armament used in air-to-ground attacks. **Fire Control Design Engineers**—(2) GS-12, $6,400 per annum. Initiates and carries out programs for the complete development of systems and components for the control of aircraft armament. **Air Development Control Engineer**—GS-9, $4,600 per annum. Administer, coordinate, and execute projects of initial design, procurement, development, and testing of air-to-ship guided missiles. **Turret Design Engineer**—GS-11, $5,400 per annum. Performs administrative phase of research, development, and testing of aircraft turrets and turret components. Applicants submit Standard Form 57, application for Federal employment (available at any post office) to: Department of the Navy, Bureau of Aeronautics, Personnel Division, Attention: Aer-PE-22, 19th and Constitution Ave., N.W., Washington 25, D.C.

Physicist, Electrical or Mechanical Engineer—Graduate engineer for design, development, and testing of flight-test instrumentation. Must be capable of electronic design work associated with servo systems, strain-gage measuring circuits, and other type instruments used in flight testing. Mechanical knowledge must be sufficient to lay out installation of test equipment in airplanes and design mechanical test equipment for instrument calibration work in laboratory. One or more years of experience with background of aeronautical engineering work desirable but not essential. Cornell Aeronautical Laboratory, Inc., Employment Office, 4455 Genesee St., Buffalo 21, N.Y.

Aeronautical Engineer—Civil Service position open in office of Bureau of Aeronautics Representative, 15 S. Raymond Ave., Pasadena, Calif. Work involves administration of Government contracts for jet propulsion and other aircraft devices. Engineering degree and 4 years of progressive professional engineering experience in fluid mechanics and combustion applicable to jet propulsion required. Advanced degree and experience in wind-tunnel testing desirable. Entrance salary $6,400 a year, Grade GS-12. Applicants should submit record of education and experience on Civil Service Form 57.

Aircraft Dynamics Engineers—For research work in the fields of: subsonic and supersonic flutter, vibration, dynamic loads; stability and control of supersonic missiles; and helicopter dynamic problems. Applicants must have good background in fundamentals of applied mechanics and mathematics. Advanced degree or previous experience in field is essential. Salaries commensurate with training and experience. Cornell Aeronautical Laboratory, Inc., Employment Office, 4455 Genesee St., Buffalo 21, N.Y.

Electronics Engineer—With interest in instrumentation and automatic control to join instrument development group at the Wind Tunnels Laboratory. Starting salary $3,100–$3,825 per annum. Apply Civilian Personnel Division, Aberdeen Proving Ground, Md.

Research Engineers—The Ballistic Research Laboratories have vacancies in the grades GS-14 ($8,800) and GS-13 ($7,600) for mechanical, electrical, and electronic engineers. The positions involve evaluation of complete weapons systems including electronic and ballistic components, and the supervision of related research and experimentation necessary to obtain basic data for such evaluation. Applicants should have good background in some or all of applied mathematics, circuit analysis, fire control, analog computers, and radar and should have research experience. Address inquiries, mentioning this notice, to

The number preceding the notices represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

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Applicant must furnish transcripts of academic record, names of four persons familiar with research ability, complete resume of past experience and salary desired. All correspondence will be kept confidential.

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P. O. Box 296, Azusa, California

Commanding General, Aberdeen Proving Ground, Md., Attention: Director, Ballistic Research Laboratories.

Development or Experimental Engineer—Graduate engineer with 5 years' experience in applied engineering, preferably in development. Familiar with turbojet engines. Mechanical design ability with background in thermodynamics and combustion. Capable of supervising development tests and writing good reports. Please direct reply to Solar Aircraft Company, 2200 Pacific Highway, San Diego 12, Calif.

Thermodynamicist—Graduate engineer to perform theoretical and design analysis of gas-turbine-type power plants. Must be analytical with practical realization of manufacturing problems. Background of thermodynamics, fluid dynamics, and heat transfer necessary. Five years' experience in applied engineering in these subjects. Must be capable of writing good reports. Please direct reply to Solar Aircraft Company, 2200 Pacific Highway, San Diego 12, Calif.

Aerodynamic, Vibrations, and Senior Layout Engineers—Must have minimum of 5 years' aircraft experience, preferably in helicopters. Please submit full details concerning education, background experience, and capabilities. Address: Chief Engineer, Kellett Aircraft Corporation, Central Airport, Camden 11, N.J.

266. Aerodynamics Engineer—Minimum of 4 years' experience. For expanding program in boundary-layer control development program. Experience in boundary-layer work desirable but not essential. Submit complete experience résumé. Salary commensurate with qualifications. West Coast location.

256. Research Engineers—With experience in application of mathematical and physical theory to the analysis of servomechanism systems as applied to aircraft. **Engineers**—Experienced in flutter analysis, calculating dynamic model requirements, and correlating airplane and model data relative to flutter characteristics.

247. Aircraft Design Engineer—Old, established eastern aircraft company wants additional qualified designers. This is not an appeal for drafting and layout people but for those who, by experienced background, have proved themselves to do dependable original design work on hydraulics installations, power plants, control systems, landing gears, and mechanical devices for aircraft. It is required that applicants are willing to do their own basic design layouts. In letter of application give details of experience, age, and salary requirements.

245. Assistant Professor of Aeronautical Engineering—To teach aircraft structures, aircraft structural design, and static testing in Aeronautical Engineering Department of state university. Excellent opportunity for applicant who can assume responsibility for structures program. Send brief outline of education and experience with reply. Salary dependent upon qualifications.

Available

268. Sales Engineer—Aeronautics—Will represent Eastern manufacturer or concern on Pacific Coast. Has excellent contacts top management in the industry. Has sales office already established in Los Angeles. Can provide warehousing for local inventory. No other clients.

267. Administration—Age 31, single. A.B. degree, University of Pennsylvania. Major in administration; courses in industrial and aeronautical engineering. Almost six years in aircraft testing in last position. Desires permanent position as junior Administrative Assistant or equivalent, with opportunity for advancement. Philadelphia area.

265. Aeronautical Engineer—B.A.E., New York University. Almost two years' experience in design. Age 28. Desires position with company located in New York City or vicinity.

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Apply to: Box 1274, Station B, Ottawa, Ontario.

GRADUATE PHYSICAL ORGANIC AND INORGANIC CHEMISTS. Ph.D. required. Men with firm academic background and industrial experience for research and development work in the field of liquid and solid propellants. Should have knowledge of kinetics, thermo-chemical measurements, high-polymers, interior ballistics, resins and nitro-compounds. Firm background of mathematics, plus the ability and desire for both group and independent research.

Applicant must furnish transcripts of academic record, names of four persons familiar with research ability, complete resume of past experience and salary desired. All correspondence will be kept confidential.

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264. Executive, Assistant Project or Structures Engineer—Aeronautical Engineer with 13 years' experience, B.S. and Master's degrees. Approximately 7 years in structures covering preliminary and final stress analysis and structural design of aircraft components. Administration of structures department. Six years in general aeronautical engineering as Chief Engineer of aircraft manufacture company covering design, structural analysis, static and flight testing, as well as supervision and administration of entire engineering department. Presently Assistant Chief of Structures. Desires position of executive or administrative level commensurate with experience.

263. Aircraft Instrument Representative—Requires post in Egypt. Twelve years' experience including aircraft instrument technician and compass specialist. Specialization Courses: Instructor to Egyptian Military Air Forces, R.A.F., and Indian Air Forces; Bombsight Instructor. Inspection experience—engineering companies. Member of the Institute of Navigation (London). Superintendent, aircraft servicing and maintenance. Aircraft development experience and technical writing ability. Widely traveled—South Africa, Egypt, Palestine, Iraq, India, and Baluchistan included. At present residing in Egypt. Age 28. British.

262. Aeronautical Engineer—Eight years (1939–1947) with major airplane manufacturer as aerodynamicist and design engineer, embracing wind tunnel and flight testing in research and project work, airplane preliminary design, project chief aerodynamicist responsibility; some sales engineering with reference to military, commercial, jet-propelled, and flying-boat types of airplanes. Six years' total teaching experience; 4 years (1947 to present) as head of department, embracing applied aerodynamics and airplane design, in foreign technical institute. Some experience as consultant. N.Y.U. and M.I.T. Graduate School background. Age 35. Present contract expiring. Desires to relocate in U.S. or Canada. Receptive to propositions stressing opportunity rather than job security.

261. Mechanical Engineer—B.M.E., 1943. Experience of $6\frac{1}{2}$ years in aircraft industry includes 5 years as aerodynamicist and $1\frac{1}{2}$ years as lab analyst testing aircraft components and equipment. Desires position doing mechanical development test work. Location—Los Angeles area.

260. Pilot-Engineer—Transoceanic air-line captain and aeronautical engineer desires location in Southern California Area. Flight experience, 8,000 hours land and seaplane, currently Constellation and Boeing Stratocruiser; formerly chief test pilot for manufacturer and air line. M.S. Aeronautics, M.S. Physics. One and one-half years' manufacturer experience—aerodynamicist. Age 39; presently employed, desires change. Interested in either flying position with manufacturer or executive transport, or responsible ground position.

259. Flight-Test Engineer—B.A.E., 1946, New York University. Four years' experience in flight testing, covering instrumentation, operations, planning, data analysis, and report writing gained as a civilian project engineer at Naval Air Test Center. Experience in machine-shop practices, in wind-tunnel data analysis, and as assistant to a consulting aeronautical engineer. Will accept position anywhere in the United States. Further information on request.

258. Engineer—Eleven years in engineering and 5 years in sales as factory representative; management and some production experience; graduate of University of Michigan and Alexander Hamilton Institute of Business Administration.

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255. Flight-Test Engineer—B.Aero.E. Two and one-half years' experience in flight test and aerodynamics. Present duties include preparation of flight-test programs, flights as test engineer-observer, reduction of test data, analysis of flight-test results, and report writing. Desires position in flight-test research program. Location open. Age 24.

254. Sales Engineering Representative—Sales management experience of products requiring high-level engineering in aviation and general industry. Products electromechanical in nature can be represented from an engineering and sales standpoint in the Western states. Location of office—Los Angeles.

253. Mechanical and Aeronautical Engineer—Age 43. Seventeen years of experience in Europe, Canada, and the United States. Five years as chief inspector for Air Ministry in Warsaw; 2½ years as technical manager of factory producing instruments for aircraft; 2 years as inspector and later chief engineer with aircraft factory in Canada; 3 years as chief engineer in charge of design of jet helicopter in U.S.A.; 1 year in charge of combustion research; for 1 year conducted research on ram-jets for United States Air Force; 2 years as vice-president in charge of engineering and research of laboratory carrying on research on combustion for U.S. Army, Navy, and industry. Languages: English, French, Polish, Russian, and slight knowledge of German and Czechoslovakian.

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251. Aeronautical Engineer—B.S. in Aeronautics, Massachusetts Institute of Technology, 1936. Fourteen years' experience in aircraft and guided-missile design and structural analysis, including 7 years as project stress engineer on Army, Navy, and commercial aircraft; 3 years as project engineer on fighter and cargo aircraft; 4 years as chief of structures and project supervisor on guided missiles. Desires responsible position in project or structures department, or production engineering, entailing shop liaison. Capable of assuming full responsibility of departments. Age 36.

250. Service — Maintenance — Liaison — Administration—Purdue University Graduate, June, 1949. B.S. degree in Air Transportation. Has private pilot's license, A. & E. mechanic's license, ground instructor rating in A. & E. Five years' retail sales experience. Business administration and technical educational background. Twenty-six months in U.S. Air Force. Member of Civil Air Patrol. Desires position offering opportunity for variety of experience and advancement in service, maintenance, liaison engineering, or administrative work. Location open. Age 25. Complete résumé upon request.

249. Engineer—Graduate Cal-Aero Technical Institute, October, 1948. Holds valid C.A.A. A. & E. Mechanic's license and C.A.A. Flight Engineer's license. Currently employed as temporary mechanic for an air line on DC-6 8,000-hour overhaul. Willing to start at bottom; work or travel anywhere (especially interested in overseas work). Age 24, single.

246. Research and Development Engineer—Desires position as technical assistant to executive engineer, technical liaison and coordination engineer between technical groups or special technical assignments, or project engineer with aircraft and/or missiles company. Experience includes several years of working with internationally known authority in technical aeronautics and many years in aircraft industry. Education includes pertinent science graduate pursuits, as well as usual undergraduate training in science. Can offer suitable business and practical technical experience along with supervision in applied technical aeronautics, with early experience in basic research.

244. Field Representative—Naval Commander, retiring about January, 1951; B.S. degree from U.S. Naval Academy, Ae.E. degree from California Institute of Technology. Naval Aviator since 1935; 4,000 hours logged flight time in all types, mostly single-seater fighters. Especially qualified for field representative job; familiar with aeronautical material commands in both U.S. Navy and Air Force.

205. Mechanical Engineer—Licensed Professional Engineer. Eleven years' experience: 2 years of teaching evening classes, Washington University, St. Louis, Mo. Supervisory experience includes 3 years as Chief of Design, 1 year as Project Engineer (power plant), 1 year as Group Engineer (power plant), 1 year as Lead Man (power plant and preliminary design). Active Wright Field and BuAer contacts 1943–1945; active C.A.A. Washington contacts 1945–1946. Experienced in preliminary design (8 years), including practical estimations of manpower (shop and engineering) and material costs. Diversified experience ranges from complete airplane and guided-missile design to components, including liquid-oxygen test devices, injector plates, rocket-motor shells, high-speed bearing application, miniature power plants, and optics systems for seekers. Will consider supervisory or administrative work with a small aggressive, and well-financed group. Currently holds two Professional (P-6) Civil Service Ratings

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So precise are the requirements of these products for today's high-altitude, high-speed aircraft that some designs were declared "impossible" to fabricate.

But the practical development of such designs to the point of mass production is the day-to-day task of the manufacturing division of AiResearch. Here, over 600,000 machined parts are turned out *every month!* They are used in 640 different precision assemblies in the 8 major categories listed at the right.

So exacting is much of this work that some of the production machines themselves must be invented to accomplish objectives never attempted before. Such pioneering in manufacture — as well as in design and laboratory testing — is typical of the progressive thinking and doing at AiResearch today.

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